GAS PIPELINE ON THE YUKON RIVER BRIDGE

RESPONSE TO TECHNICAL CONCERNS

143 B

ALASKA SEGMENT

ALASKA NATURAL GAS TRANSPORTATION SYSTEM

143-B

Alaskan Northwest Natural Gas
Transportation Company

GAS PIPELINE ON THE YUKON RIVER BRIDGE

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1.0 INTRODUCTION

The Yukon River Bridge was designed and constructed to accommodate two 48-inch diameter crude oil pipelines in addition to vehicular traffic. The results of a preliminary assessment to investigate the feasibility of placement of a 48-inch diameter gas line on the bridge were presented by NWA in a joint meeting with representatives from the State of Alaska, the office of the Federal Inspector and ALYESKA Pipeline Service Company. Two alternative designs were presented:

- Alternative A

  Place the gas pipeline on the west pipeway, which is currently vacant.

- Alternative B

  Place the gas pipeline beneath the deck and between the box girders of the bridge, supporting the pipe at intervals on sliding plates framed into the webs of the box girders.

Drawings depicting details of these alternative placement methods are contained in Appendix B.

During the discussion that followed the presentation, some technical concerns were expressed by the agencies regarding structural details of the proposed alternatives. The concerns are summarized below:

- Adequacy of design of the proposed modifications to the existing bridge diaphragms required for Alternative B. This concern is addressed in Section 3.0.

- Adequacy of design of the proposed modifications to the existing bottom flange of the box girder of the bridge required for Alternative B. This concern is addressed in Section 4.0.

- Possible fatigue in the pipe both for Alternatives A and B resulting from vehicular traffic on the bridge. This concern is addressed in Section 5.0.

- The effect on the bridge structure resulting from a postulated hole in the gas pipeline both for Alternatives A and B. This concern is addressed in Section 6.0.

A subsequent meeting was held in Houston with the ALYESKA Pipeline Service Company. As a result of this meeting it was decided to provide additional clarification concerning the live load levels used in the structural analyses.

This report addresses the agencies concerns regarding the placement of the gas pipeline on the Yukon River Bridge and shows that both the suggested methods are technically sound and the agencies concerns unwarranted. A summary of the analytical techniques used in addressing the agency concerns and the conclusion drawn from the analyses appears in the next section.

2.0 SUMMARY AND CONCLUSIONS

2.1 DIAPHRAGM MODIFICATIONS

An investigation through finite element analytical procedures examined the adequacy of the modified diaphragms due to the proposed gas pipeline installation beneath the deck and between the box girders of the Yukon River Bridge.

It was determined that the modified diaphragm has a stress increase of 14 percent over the stress of the diaphragm in the existing bridge. The maximum stress of the modified diaphragm and the existing diaphragm were 7.60 Ksi and 6.69 Ksi respectively. Both of these stresses conform to AASHTO code requirements. The study centered around investigating conditions at Pier 6 since preliminary analysis indicated that the diaphragm at this pier contained the highest stresses. The conclusion can be made that the modified diaphragms at all piers will perform adequately and will meet code requirements.

2.2 BOX GIRDER MODIFICATIONS

The description of the procedure used to size the plates required to strengthen the superstructure was reviewed. The process follows accepted and conservative procedures for strengthening existing structures. The process adequately handles the fact that additional plates will not participate in resisting existing loads. It was concluded that this analysis is acceptable. The provisions for the bolt arrangement were reviewed. Relevant AASHTO specifications cited were followed in the analysis. A review of the basis of such provisions was made and no exceptions were found for the design situation analyzed.

It was concluded that adequate connection strength will be developed to resist the additional loads. Experimental evidence is cited in the report to verify the conclusion. It is also noted that these provisions are used and found acceptable in all highway bridges and their adequacy can perhaps best be cited by the excellent history of performance of bolted connections in such bridges, including the Yukon River Bridge itself.

A detailed stress investigation was made of the local stress field around the bolt holes. The investigation specifically addressed the transient situation in which the bolt holes were made without the connection being completed. It was recognized that stress risers near the bolt holes exist but attenuate very rapidly with radial distance from the hole. However, when using very conservative assumptions, it was demonstrated that the local material around the holes would still be able to provide a significant safety factor against local failure.

2.3 PIPELINE FATIGUE

An investigation was made of the stresses caused in the pipeline due to AASHTO HS20-44 truck loading plus impact.

It was concluded that the stress range is well below the allowables using the generally acceptable method of an equivalent static loading analysis. The possibility of a higher impact factor was examined and, although not discounted in certain postulated situations, is seen to have no detrimental effect on the conclusions. Resonant effects from the bridge on the pipeline were discounted using simple models.

2.4 THRUST FROM POTENTIAL LEAKAGE

An investigation was made of the effect of a concentrated load applied to the pipeline to simulate a hole in the pipeline. Critical events were identified corresponding to the position of the hole on the circumference of the pipeline. Such events would correspond to the onset of a failure mechanism but would be considerably below actual failure. Loads corresponding to the onset of these critical events were found and an associated hole size was identified.

For the pipeline the critical event was the negation of a reaction load due to a pipe hole in the bottom of the pipe. The hole size required to equal the reaction load was 18 square inches, or a 4.8 inch diameter circular hole.

For the bridge the critical event was first contact of the pipeline with the web of the bridge due to a hole in the side of the pipe pushing the pipe on its frictional supports in toward the web. The hole size required for contact was 22 square inches, or a 5.3 inch diameter circular hole.

2.5 CLARIFICATION OF LIVE LOAD LEVELS

Wind induced stress cycles for the fatigue analysis is the controlling load case for the substructure analyses of the Yukon River Bridge.

It was shown that, according to accepted equations for fatigue design, the number of load cycles would have to be drastically reduced to allow acceptance of the fatigue critical details. Strengthening of the piers is recommended for both alternatives.

AASHTO lane loading is the controlling load case for live load for the superstructure analysis of the Yukon River Bridge. It was combined with dead load effects to produce the design stresses.

For Alternative A such stresses would remain below allowables so no superstructure strengthening would be required. For Alternative B, such loading would produce stresses which would require reduction through superstructure strengthening. It was demonstrated that AASHTO truck loading would not prompt such a recommendation. It was concluded that lane loading, especially when applied to the remote Yukon crossing, is adequately conservative.

3.0 DIAPHRAGM MODIFICATIONS

3.1 STATEMENT OF CONCERN

- o Adequacy of design of the proposed modifications to the existing bridge diaphragms required for Alternative B.

Placement of pipe under the deck would require modifications to the existing diaphragm to accommodate pipe passage at the piers and abutments. Questions were raised about the adequacy of the proposed modifications. Appendix C, Sheet 31 shows the proposed changes. A study has been performed to investigate the modified diaphragm details under erection and operating load conditions by considering a full lane load on one traffic lane. Such a loading would be expected to produce the maximum moment on the diaphragm (which provides torsional restraint).

3.2 DESIGN LOADS

It was assumed that traffic on the east bridge lane during construction would be allowed. Live loads were therefore placed on this lane for all analyses in order to maximize the torsional moment (the existing oil line is currently cantilevered from the east side).

The values of the design loads relevant to this analysis are given in Table 1.

The design loads considered are arranged in expected combinations. The group loads investigated are the following:

- o Group Load 1
  - Dead: Existing bridge and oil line (operating conditions).
  - Live: HS20-44 full lane load applied on the east lane so as to maximize the torsional effect.
  - Impact: from AASHTO.
- o Group Load 2
  - Dead: Existing bridge and oil line (operating conditions) and gas line (operating conditions).
  - Live: HS20-44 full lane load applied on the east lane so as to maximize the torsional effect.
  - Impact: from AASHTO

- o Group Load 3

  Same as preceding with one exception. The gas line is not installed. The bridge is under the erection condition. By inspection, this condition will not be a controlling load. In addition, the allowable stresses for this group Load are 150% (temporary loads) of the basic unit stress.

3.3 ANALYSIS PROCEDURES

A three dimensional finite element model (Figure 1) was developed to describe the Yukon River Bridge. The ANSYS computer program, a large scale general purpose engineering analyses computer program, was used for the analysis. An initial run of the model, in which all diaphragms were modelled by beam elements, indicated that the diaphragm at pier 6 was the location of highest stress in all diaphragms. For this reason, the finite element model for the bridge was modified by a model in which the equivalent beam elements modelling the diaphragm at pier 6 were replaced by a combination of plate and beam elements representing individual elements at the diaphragm.

Figure 2 shows the model at the diaphragm used in the analysis of the existing condition, i.e. Group Load 1 of Section 3.2. Figure 3 shows the model of the proposed modified diaphragm used in the analysis, i.e. Group Load 2 of Subsection 3.2. Details of the model and analyses are contained in Appendix C.

3.4 RESULTS

Computer stress analysis results of the existing configuration indicate that, in general, the stresses throughout the diaphragm at Pier 6 are low. The maximum stress from Group Load 1 (See Figure 2) occurs in a plate element with a value of 6.69 KSI. Analysis also indicates low stresses throughout the proposed modified diaphragm at Pier 6. The maximum stress from Group Load 2 (See Figure 3) occurs in the same plate element with a value of 7.60 KSI. The maximum stress of the modified diaphragm due to gas line installation is 14% greater than the diaphragm in the existing bridge. The stresses in both the existing diaphragm and the modified diaphragm are below AASHTO Code allowables as shown in the calculations in Appendix C.

A comparison of the section properties of the existing diaphragm and the modified diaphragm are shown in the calculations in Appendix C, pages 41 through 44.

The moments developed in the box girder for Group Load 1 and 2 are as follows:

<u>Group Load 1</u>

	MX	MZ
East Girder	12,441 IN-K	627,814 IN-K
West Girder	11,135 IN-K	540,108 IN-K

<u>Group Load 2</u>

	MX	MZ
East Girder	12,472 IN-K	733,031 IN-K
West Girder	13,068 IN-K	643,215 IN-K

4.0 BOX GIRDER MODIFICATIONS

4.1 STATEMENT OF CONCERN

- Adequacy of design of the proposed modifications to the existing bottom flange of the box girder of the bridge required for Alternative B.

For Alternative B (placement of pipe under the deck), the bottom flanges of the box girders were recommended to be strengthened by bolting additional plates to the inside of the box girder. Questions were raised about the procedure used to size the plates as well as the increased stresses on the net section where the holes will be drilled for the bolts. Appendix B, Drawing Number 4680-13-11-W-SK-064K shows the recommended strengthening.

4.2 DESIGN LOADS

The values of the design loads are given in Table 1. The loads investigated relevant to this discussion are the following:

- Case 1 - Existing Dead Load

  Existing bridge and oil line (operating conditions).

- Case 2 - Existing Dead Load + Future Gas Line

  Bridge, oil line, and a gas line under the deck including all appurtenances (operating conditions).

- Case 3 - Existing Dead Load + Future Gas Line + Future Oil Line

  Bridge, oil lines on both pipeways, gas line under the deck including all appurtenances (operating conditions).

- Case 4 - Existing Dead Load + Future Gas Line During Hydrotest

  Bridge, oil line and a gas line under the deck including all appurtenances (this condition did not control).

- Case 5 - Live Load + Impact

  AASHTO HS20-44 loading including impact factors.

4.3 SIZING OF PLATES

4.3.1 Analysis Procedure

The moments in the box girders due to dead weight load cases were found by using the program ANSYS.

Another program (Michael Baker Jr., Inc. in-house program #270) was used to find the moment due to live load. AASHTO HS20-44 loading was specified. The distribution factor was found by AASHTO specifications and verified by a separate ANSYS analysis. Program #270 calculates the moment influence line. Maximum positive and maximum negative areas under the influence line are computed to determine maximum positive and negative live load lane moments. For truck loadings, concentrated loads are placed to simulate wheel loading. The axle spacing is varied to provide maximum moments. The truck is placed in all allowable positions to determine the maximum moments. The final moments in the output are multiplied by impact and distribution factors.

For a particular point of interest in the box girder the following were defined:

M_{DL1} = moment resulting from Case 1.

M_{DL2} = maximum moment resulting from Case 2 or 3.

M_{LL} = moment resulting from Case 5.

The existing dead load stress and reserve capacity stress were then determined as follows:

Existing dead load stress $\sigma_1 = M_{DL1}/S_{BOT}$

Reserve capacity stress $\sigma_2 = \sigma_{ALL} - \sigma_1$

where:

S_{BOT} = existing section modulus of the bottom flange

σ_{ALL} = allowable stress of bottom flange as per AASHTO

Any new plates to be added to this section must be added with the consideration that the new plates will not share in resisting the existing dead load stress (since they are being added while this dead load effect is being fully resisted by the existing structure). Then, in order not to overstress the existing material:

$$S'_{BOT} = (M_{DL2} + M_{LL} - M_{DL1}) / \sigma_2$$

where:

S'_{BOT} = Required section modulus of bottom flange

The calculation of S'_{BOT} required a trial and error procedure in which various plate sizes were added, the geometrical properties computed and compared to the required value. The plate length was found by calculating the point at which the existing material would exhibit no overstress under the final configuration. An additional terminal distance was added to develop the design resistance through the bolting configuration.

4.3.2 RESULTS

The results of the analysis indicated that strengthening would be required at plate transition areas in all spans. Appendix B - Drawing Number 4680-13-11-W-SK-064K shows the proposed placements of the reinforcing plates (two locations in each box girder in each of the six spans for a total of 24 locations).

Since the plates will have to be manhandled into position, the weight of each piece was calculated to find the feasibility of the handling operation. Each location in the box girder that required strengthening will have two plates (each plate being half the required width) to ease the handling operation. If the weight was still found to be excessive, the thickness of each plate would be halved (requiring four plates to be carried to that location).

4.4 HIGH STRENGTH BOLT CONFIGURATION

4.4.1 Analysis Procedure

AASHTO provisions were followed in designing the configuration of the bolting arrangements. Relevant requirements are:

- "Except as otherwise provided herein, connections shall be designed for the average of the calculated design stress and the strength of the member, but they shall be designed for not less than 75 percent of the strength of the member." (Art. 1.7.16)

- "The diameters of the hole shall be taken as 1/8 inch (3.2 mm) greater than the nominal diameter of the rivet or high strength bolt, unless larger holes are permitted in accordance with Art. 1.7.22" (Art. 1.7.44(M))

- "The minimum distance from the center of any fastener to a sheared or flame cut edge shall be.... For 7/8 inch fasteners, 1½ inches (22.22 mm - 38 mm)". (Art. 1.7.22 (E))

- "The minimum distance between center of fasteners shall be three times the diameter of the fastener but, preferably, shall not be less than the following:

  - for 7/8 inch fasteners, 3 inches (22.22 mm - 76.2 mm). (Art 1.7.22(C))

- "The strength of members connected by high strength bolts shall be determined by the gross section for compression members. For members primarily in bending, the gross section shall also be used, except that if more than 15 percent of each flange area is removed, that amount removed in excess of 15 percent shall be deducted from the gross area" (Art. 1.7.15).

The basis for these provisions are contained in Reference 6.

Since the calculated design stress in the connection would be based on the reserve capacity of the member, the first provision was satisfied by designing the connections to develop 75 percent of the strength of the member. Since the maximum reserve stress σ_2 is 12.2 Ksi and the strength of all members considered is 27 Ksi, then 75 percent of the strength (0.75x27=20.3 Ksi) provides a connection design strength that is 40% higher than the calculated design strength. This provision was included to provide an adequate safety factor for slip resistance of the connection. The fact that the connection was well above the calculated design strength gives an indication of the added conservatism of this provision as applied to this situation.

The second provision is conservative in calculating the net section since it is observed that "Bolts are generally used in holes 1/16 inch (2 mm) larger than the nominal bolt diameter." (Reference 6)

The next two provisions are intended to prevent local plate failure by ensuring that the shear resistance of the plate can resist the local bearing action by the bolt.

The last provision is designed to require tension members to yield on the gross section before failure occurs on the net section. This can be expressed in the equation:

$$A_n/A_g \geq \sigma_y/\emptyset\sigma_u$$

Where σ_u and σ_y represent the tensile strength of the net section and the yield stress of the material at the gross section, $\emptyset$ is a reduction factor to ensure that yielding of the gross section develops before the tensile capacity of the net section is reached; $\emptyset$ also prevents yielding of the net section under working loads. For A537 steel the minimum yield stress is 50 Ksi, while the tensile strength (from coupon tests) is 70 Ksi. Thus σ_y/σ_u is 0.71. Using a $\emptyset$ factor of 0.85 produces a requirement that $A_n/A_g \geq 0.84$. (Note that using σ_u from coupon tests is conservative since the ultimate strength of perforated plates at the net section is higher than coupon ultimate strength due to the "reinforcement" or biaxial stress effect created by the holes. For A441 steel, with a yield of 42 Ksi, the increase of ultimate strength is five percent when $A_n/A_g = 0.85$. This provides added conservatism). With the allowable of 27 Ksi and the A_n/A_g ratio equal to 0.85, a net section stress of 31.8

Ksi could result. This provides a factor of safety with respect to the ultimate load of 2.2. For the proposed strengthening of the Yukon River Bridge, six 1-inch holes will be made in the 61-inch bottom flange so the A_n/A_g is 0.9 to provide a factor of safety with respect to ultimate of 2.3. "Moreover, the net section stresses have a very localized character and do not influence the behavior of the connected members" (Reference 5, p. 133).

Actual load tests of beams with flange splices provided the conclusion that: "In all tests the maximum resisting moment was equal to, or slightly greater than, the theoretical plastic moment... The gross section plastic moment was obtained although...this was approximately 23% greater than the theoretical net section plastic moment" (Reference 7, p. 107). This provided strong evidence that the completed connection would develop the full design strength.

To investigate further the nature of the net section stresses and to quantify their behavior, a computer analysis using the finite element method was made. The analyses used the program PSI, developed for NWA to investigate plane strain/stress situations. The analyses features automatic mesh generation through solution of the planar Laplacian equation. The mesh generated for this analysis is shown in Figure 4 and consists of 325 nodes and 288 elements (a grid of 24x12 elements). Since the bolts to be used are 7/8 inch, the hole was sized at one inch diameter. The minimum distance between holes on the bolt line perpendicular to the longitudinal stress path is 6.75 inches. Symmetry conditions allowed the model to contain only one quarter of the bolt hole with no movement allowed in the transverse direction at the mid line and 3.375 inches from midline of the bolt hole. The longitudinal length of the model was 6.75 inches with the load applied at the extreme end. Even though the minimum distance between bolt lines perpendicular to the longitudinal stress path is three inches, the length was extended to find the distance at which the stress contours would approach those expected in the gross section. Note that no strength or extra conditions were added for the bolt itself. Thus, the condition may be thought to represent most closely the case wherein the holes are drilled, but the bolts not yet inserted. All material was assumed elastic. The thickness was input as 0.75 inches.

A load of 1 pound/element was applied as a uniform load on the longitudinal direction at the extreme end of the mesh. On the gross section this would correspond to a stress of 4.74 psi, (12/[3.375x0.75]).

4.4.2 Results

The displaced shapes and stress contours are contained in Appendix D. The stress contours for the longitudinal stress (SIGMAX) indicates that the stress concentration attenuates rapidly with radial distance from the hole. At the periphery of the next hole location the stress contour has nearly returned to the gross section value (within 5%). Thus, at the spacing selected no significant stress interaction from localized stress concentrations around bolt holes is expected and, thus, this simple model is adequate. The rapid attenuation also provides indirect evidence for the adequacy of AASHTO provisions regarding minimum spacing of bolt holes.

The SIGMAX (or maximum principal stress SIGMA1) stress contours indicate that the net section stress (12/(0.75x [3.375-0.5]) = 5.56 psi is not exceeded outside a radius equal to about one half the bolt diameter (0.5 inches).

At the bolt hole periphery a stress concentration factor of about 2.1 (based on the gross section stress) can be found from the stress contours of SIGMAX or SIGMA1. Since the maximum gross section stress allowable is 27 Ksi, such a factor would imply a safety factor against local failure of (70/[27x2.1]) = 1.23. Such a computation is very conservative for the following reasons:

- o the inclusion of inelastic effects would tend to redistribute the stress.
- o the ultimate strength would be increased because of the biaxial effect.
- o actual coupon tensile strength is usually above minimum specifications and ranges from 70 to 100 Ksi (Reference 6, p.11).
- o the loading required to reach yield is based on conservative loads, especially for the live load.

  It should be noted that the testing program of Reference 7 also tested members in which bolt holes were placed in the flange of the members but left open. This section also developed the full plastic moment. As stated in the report, "Although the evidence is not extensive, the most logical explanation for obtaining a resistance greater than that of the net section lies in strain hardening of the flange material at the side of the holes" (Reference 7, p. 107).

5.0 FATIGUE CONDITIONS OF PIPELINE

5.1 STATEMENT OF CONCERN

- Possible fatigue in the pipe both for Alternatives A and B resulting from vehicular traffic on the bridge.

As live load acts on the bridge, members can be expected to experience a cycle in stress centered around the mean (dead load) stress level. Such cyclic stress levels were checked for bridge members against AASHTO fatigue provisions. The additional question was raised as to the effect of AASHTO truck loading on cyclic behavior in the pipeline. Such a question involves the load transfer from the deck of the bridge to the pipeline supports. A study was initiated to investigate the details of the effects of live load on the pipeline.

5.2 DESIGN LOADS

Vehicular live load effects (AASHTO HS20-44), including impact factors were used to develop the loadings for use in the analysis.

Truck loading rather than lane loading was used to determine the stress range since lane loading is unlikely in general and even more unlikely at the Yukon River Bridge. Such a viewpoint is reinforced by the statement, "At most locations on a highway the trucks are rarely, if ever, spaced closely enough to be represented as a uniform lane loading. Therefore, lane loading need not be considered in fatigue design unless the bridge is at a location where unusual conditions cause abnormally close truck spacings to occur fairly often." (Reference 3, p. 1179)

The number of cycles of loading was based on the AKDOT report that about 100 vehicles travel over the bridge each day (Appendix A). For conservatism, a value of 250 ADTT (average daily truck traffic) was used to derive the value of 250,000 design cycles of loading.

5.3 STATIC ANALYSIS

5.3.1 Analysis Procedure

The ANSYS finite element program was used to determine the stress range in the pipeline. AASHTO HS20-44 loads were used to determine the nodal forces applied to the nodes at the deck level. The forces included impact factors as per AASHTO specifications. The placement of the trucks on the bridge was determined from the bridge moment influence line so as to attempt to maximize the effect of the loading. One run was made to maximize the positive stress range in the pipeline and another run was made to maximize the negative effect in the pipeline. The amplitude of this stress range was then compared to the allowable stress range for 250,000 cycles of loading as derived from ASME Boiler and Pressure Vessel Code, Section VIII.

Both Alternative A and Alternative B were investigated. Details of the investigation are contained in Appendix E.

5.3.2 Results

The maximum stress range in the pipe was found to be 3.31 Ksi. Referring to Reference 10, Appendix 5, Article 5-1, the alternating stress intensity was taken as 0.5 of this range or 1.65 Ksi. For 250,000 cycles of loading the allowable value of the alternating stress was taken from Ref. 10, Fig. 5-110.1 as 19 Ksi. Thus, the fatigue provision is met with a factor of safety of 19/1.65 or 11.5.

5.4 DYNAMIC EFFECTS

5.4.1 Analysis Procedure

As the truck travels across the bridge, dynamic effects magnify the stress that would be calculated by simple static analysis. This magnification is ". . . usually accounted for in design by applying an impact factor to the calculated static stresses." (Reference 9) As was mentioned, the AASHTO impacts were applied to the truck loadings used in the static analysis. This factor, for the 410 foot span, was:

$$I = \frac{50}{L + 125} = 9.3\%$$

However, it was recognized that the AASHTO code for impact was less conservative than other codes, such as the new Ontario Bridge Code (Reference 3). To understand the magnification due to dynamic effects, the several factors which underlie the analysis are explained below:

For a single load of constant magnitude acting on a simple span, the dynamic part of the midspan moment is given by:

$$M_d = \frac{\pi^2 Wl}{48} \left(\frac{a^2}{1-a^2} \sin \frac{2\pi at}{T} - \frac{a}{1-a^2} \sin \frac{2\pi t}{T} \right)$$

where: W = weight of moving load

l = length of beam

a = speed parameter

t = time the load has been on the beam

T = period of beam

This effect is maximized when the first sine term is 1 and the second is -1. The impact factor, I, is found by dividing this maximum value by the static moment (Wl/4), so:

$$I = \frac{\pi^2}{12}\left(\frac{a^2}{1-a^2} + \frac{a}{1-a^2}\right) = \frac{\pi^2}{12} \quad \frac{a}{1-a}$$

The speed parameter is given by:

$$a = \frac{vT}{2\ell}$$

where: T = period of structure

v = velocity of the moving force

For the first vertical mode of the Yukon River Bridge (T = 2 sec) (Reference 2), with a single span length of 410', and assuming a speed of 60 mph,

$$a = \frac{1}{2} \times \frac{60 \times 5280}{3600} \times 2 \times \frac{1}{410 \text{ ft}}$$

$$= 0.215$$

so, $I = 0.23$

The effect of several moving loads with fixed spacings (such as multiaxle trucks) produces a more complicated relationship since the impact curve undulates due to changing phase relationships. However, the single load provides a reasonable approximation to this situation (Reference 9). The effect of the variation in force from the truck due to the spring effect of the truck axle should be small since the ratio of truck weight to weight of the bridge span is small, $(72^K/(410' \times 8^K/\text{ft}) = 0.02$. Assuming that oscillations in the truck are caused by uneven surface, the oscillations are limited to about 15 percent of the static force (Reference 9). Assuming that these effects combine directly with the former dynamic effects (a very conservative assumption assuming in-phase reinforcement of effects), the value of the impact factor should be bounded by I = 0.38. Such a value is in general agreement with the more conservative Ontario Bridge code.

This factor does not include consideration of a bump at a critical location which may increase the impact value . Actual recorded values of stress range impact factors for continuous span bridges vary from 0.05 to 0.54. Even though the authors of Ref. 9 conclude that ". . . present AASHTO formula are fairly typical and, therefore, are generally appropriate for fatigue calculations," the highest recorded value of 0.54 was used for this effect.

Finally, the possibility of bridge inertial effects were considered: A dynamic magnification could result if a forcing function, represented by a steady state oscillation, has a frequency similar to the frequency of the excited structure. This amplification, expressed as the ratio of dynamic to static response is given by:

$$a = 1/\ [(1-t^2)^2 + (2pt)^2]^{1/2}$$

where: t = ratio of frequency of external force to frequency of the excited system

p = percentage of critical damping of excited system (Reference 11)

For the bridge the period of the primary vertical mode is 2 seconds (Reference 2). Assume that the forcing mechanism (the truck loading) is of such type and duration as to cause a steady state oscillation of the bridge (which would occur at the primary vertical frequency). If this is viewed as a forcing function on the pipe support nodes then the amplification factor can be used to find the effect on the pipeline.

5.4.2 Results

Even using the worst of all reported impact factors and assuming that this factor occurs for all cycles of loading throughout the history of the bridge, the stress range in the pipeline was still below allowables by a factor of:

$$\frac{19}{1.65} \times \frac{1.09}{1.54} = 8.2$$

As seen in Appendix E, the natural frequency of the pipeline was (conservatively assuming simply supported conditions) calculated as 15.8 sec^{-1}. Thus t = 0.032. Assuming no damping (p=o) the amplification would be given as 1.001. Any damping would decrease this result. Thus, any resonant effect was discounted.

6.0 THRUST FROM POTENTIAL PIPELINE LEAKAGE

6.1 STATEMENT OF CONCERN

- The effect on the bridge structure resulting from a postulated hole in the gas pipeline both for Alternatives A and B.

The gas pipeline is required by 49CFR192 to have an increased safety factor when located on the bridge (this results in 0.72-inch thick pipe or a 20% increase above the cross-country design). Further, special attention has been given to fracture control for this line. In addition, a study was performed to investigate the effects on the integrity of the crossing in the event that a hole develops in the line on the bridge. The force developed was found from the reaction of the escaping gas, i.e., no fire, rupture, or explosion was assumed to accompany this event. Special attention was given to the integrity of the bridge structure, as opposed to the integrity of the pipeline itself.

6.2 DESIGN LOADS

The hole was postulated to occur anywhere along the crossing and anywhere around the pipe periphery. Therefore, to bound the effect, the worst locations corresponding to this event were chosen to be analyzed.

The actual value of the force will depend on the size of the hole. It was decided to identify the magnitude of the force which would cause a critical event and then to calculate the size of hole to which the force would correspond. An arbitrary load of 10 Kips was used in all computer runs and critical event loads were found by simple scaling of the results.

6.3 ANALYSIS PROCEDURE

A combination of manual and computer techniques were used for the analyses.

It was assumed that the hole would occur at a pipe support node since this would maximize the local effect on the bridge. Any other location would distribute the force between adjacent supports.

For the case where a force is directed vertically up the critical event condition was considered that in which the magnitude of the force would be equal to that of the normal reaction. This would be a case of pipe instability; no damage potential to the bridge would exist at this load.

For the case where a force is directed vertically down the pipeline support framing was analyzed by manual techniques to find the load at yield, yield being defined as the critical event condition for this case. The main girders of the bridge were analyzed by the computer program ANSYS to find the vertical load to yield them. In this latter analysis three runs were performed:

- The operating condition of an oil line on the east pipeway and the gas line on the west pipeway.
- The above conditions plus a 10 Kip vertical load on the gas supports at the center of the center span.
- The above conditions plus a 10 Kip vertical load on the gas supports near the center of the first span.

The first analyses served as the reference case. The second analysis was an attempt to maximize the moment increase. The third analysis was an attempt to maximize the stress increase at the most highly stressed transition area in the bottom flange. Results for Alternative B were assumed similar.

For the case where the pipeline is on the west pipeway and the force is directed horizontally out from the bridge, the critical event condition was considered to be the load at yield of the bumper support system. The loss of pipe support may follow such an event; however, no damage potential to the bridge would exist.

For the case where the force is directed horizontally in toward the web of the girder, the movement of the pipe must first be such as to allow contact of the pipe with the web of the girder before there is damage potential to the bridge. Contact of the pipeline with the web was defined as the critical event. The movement of the pipe on the slide supports when subjected to a horizontal force was analyzed by an ANSYS run. This run assumed the horizontal force was placed at the pipe support node centrally between the pipe anchor at pier 4 and a bumper stop mounted on the web in the first span. To maximize movement a low value of the coefficient of friction (0.05) was used. The critical force was assumed that in which the pipe bends enough between the horizontal support points so as to close the initial gap between the pipe and web.

6.4 RESULTS

The study indicated that:

- The critical load for assessing damage potential to the pipeline would be that from a hole in the bottom of the pipe jetting the pipe up off its supports. This hole was estimated to be about 18.7 square inches, which is equivalent to a 4.8 inch diameter circular hole.

- The critical load for assessing damage potential to the bridge would be that from a hole jetting the pipe in toward the web of the box girder. This hole was estimated to be about 22.4 square inches, which is equivalent to a 5.3 inch diameter circular hole.

It is noted that the hole sizes predicted correspond to loading events which are not failure events. Since the hole sizes were so large, i.e., indicating the high forces required before the onset of the defined critical events, it was not necessary to assess actual failure loads due to the load mechanism. Thus, in the case of the critical event for the bridge, i.e. a horizontal load pushing the pipe toward the web, the "critical load" corresponds to the force required for the pipe to contact the web. Considerably more force would then have to be exerted to fail the web and, in turn, fail the girder. Even in that case the bridge will not collapse and would be able to withstand light vehicular loading (Reference 2).

7.0 CLARIFICATION OF LIVE LOAD LEVELS

7.1 STATEMENT OF CONCERN

Strengthening of the Yukon River Bridge is recommended as a result of the stresses derived from analyses containing live loads. The substructure is recommended to be braced due to the fatigue analysis under wind loading. Although no superstructure strengthening is required for Alternative A, strengthening of the bottom flange of the box girder is required for Alternative B as a result of the analysis under AASHTO lane loading. At a meeting in Houston with Alyeska Pipe Service Company, it was agreed to review the controlling live load values and evaluate their significance in this application.

7.2 DESIGN LOADS

For the substructure analysis, it was concluded that the addition of extra framing members, the pipeline(s) and other appurtenances would not prompt any strengthening recommendation under AASHTO group loading combinations.

However, in addition to the above analyses, AASHTO fatigue stresses due to wind loading were investigated. This loading condition considered the application of the maximum wind loads applied to the pier in one direction and then reversed. The maximum wind load was derived from the design wind speed of 80 MPH, which was used in the original bridge design (Reference 2). The value of 80 MPH also agrees with recent recommended design isotachs for bridges. (Reference 3).

The number of cycles of loading considered was 100,000 which corresponds to the AASHTO provision: "The number of cycles of stress range to be considered for wind loads in combination with dead loads, except for structures where other considerations indicate a substantially different number of cycles, shall be 100,000 cycles." (Reference 4, Art. 1.7.2.B).

For the superstructure analysis, the loading combination which prompted the recommendation that the bottom flange of the box girder be strengthened was based on AASHTO lane loading since it controlled over AASHTO truck loading.

7.3 ANALYSIS PROCEDURE

The analysis of the wind conditions was performed by a combination of manual and computer analyses. The wind load, expressed as a force per unit area, was transformed into a force per length by multiplying by the projected area of the bridge. Results were monitored at several locations in the substructure. The allowables were based on the identification of fatigue critical details according to recent AASHTO specifications (Reference 4).

According to the AASHTO specifications fatigue critical category E details exist in the columns and column struts which result in very low permissible live load stress levels. (Note that these AASHTO provisions are considerably more stringent than the provisions which would have been applicable during original design). Using this criteria, category E details in the columns (non-redundant members) allow only 12.5 Ksi.

For the superstructure analysis, the bridge was analyzed under the following conditions:

- The existing crude oil line and an operating gas line under the deck.
- Crude oil lines on both existing pipeways and an operating gas line under the deck.
- Crude oil lines on both existing pipeways and a gas line undergoing hydrotest under the deck. (This case never controlled since the design allows an increase for temporary loads.)

The allowables were based on the criterion that a permissible overstress of six percent over the established design stress was acceptable.

7.4 RESULTS

For the substructure analysis the stress range was found to be above allowables in several areas of the piers. At the base of pier 5, for example, a stress of about 40 Ksi was found. This overstress prompted a recommendation for strengthening the columns by adding cross bracing elements which would reduce the stress range to tolerable levels. It is noted that the provisions do allow for increases in the allowables if the number of cycles can be reduced. However, using the formula (Reference 5):

$$N_i = A S_{ri}^{-3}$$

where Ni is the fatigue life Sri is the applied stress range, and A is a function of the fatigue behavior of a detail then it can be seen that the number of cycles must be reduced to:

$$N = \left(\frac{40}{12.5}\right)^{-3} 100,000 = 3052 \text{ cycles}$$

for the provision to be satisfied. (Note: it is not clear that the fatigue life formula holds in this range so such an extrapolation should be considered approximate).

Although no expert aerodynamic authority was sought in this issue, it appears unreasonable that such a drastic reduction in the number of stress cycles could be achieved by site-specific studies.

For the superstructure analysis, the controlling load case to derive the live load effect was AASHTO lane loading. It was found that strengthening of the bottom flange of the box girders at plate transition areas in all spans would be required. The strengthening consists of increasing the plate thickness of the bottom flange by bolting additional plates to the inside of the box girders.

Using AASHTO truck loading, the stress would be reduced to a point where no superstructure strengthening would be required (Table 2). If a permissible overstress of 6 percent is tolerable, the AASHTO truck loading could be increased by about 30% before strengthening would be required. Thus, even though AASHTO provisions specify lane loading for structural analysis, the probability of a vehicular loading on the Yukon River Bridge approximating AASHTO lane loading is remote and, therefore, its use in the analysis is quite conservative.

8.0 TABLES

DESIGN LOADS

Designation	Value	Reference
DEAD LOAD	o Gas pipeline: 364 lb/ft for 48" OD x 0.720 w.t. API 5LX/5LS, Grade 70 38 lb/ft for insulation/jacket 80 lb/ft for maximum gas weight 745 lb/ft for test water weight 580 lb/ft for pipe shoes, support framing and walkway	NWA Project Criteria
	o Oil pipeline and appurtenances: 1450 lb/ft per pipeway	As-Built Drawings & AKDOT recommendation Appendix A
	o Protective cover for oil pipeline: 165 lb/ft per pipeway	Meeting with AKDOT, Appendix A
	o Bridge weight: 810 lb/ft 2" asphaltic wearing surface 3310 lb/ft Box Girders	As-Built Drawings
DESIGN LIVE LOAD	o AASHTO HS20-44:	AASTO 1980
IMPACT FACTOR FOR LIVE LOAD	$I = \frac{50}{L+125}$ where: L = span length in feet	AASHTO 1980

TABLE 1

TRUCK LOADING VS. LANE LOADING

Point	(K-ft) D. L. Mom	(K-ft) L. L. Mom. Lane	(KSI) Stress Bottom	(K-ft) L. L. Mom. Track	(KSI) Stress Bottom
1.213	24436	7880	29.17	4554	26.16
1.509	24060	10949	31.60	5885	27.03
2.373	22739	10402	29.91	5487	25.5
2.627	22283	11339	30.34	5554	25.12
3.373	22042	11365	30.15	5574	24.92
3.627	22157	11570	30.44	5579	25.03

Stress calculated at transition areas using least section modulus.

Allowable = 27 Ksi, 6% over allowable = 28.6 Ksi

All live load values include impact factors.

$S_{BOTT} \div 12"/ft = 1108$

Results symmetric about pier 4.

TABLE 2

9.0 FIGURES

ANSYS PLOT OF COMPUTER MODEL
YUKON RIVER BRIDGE

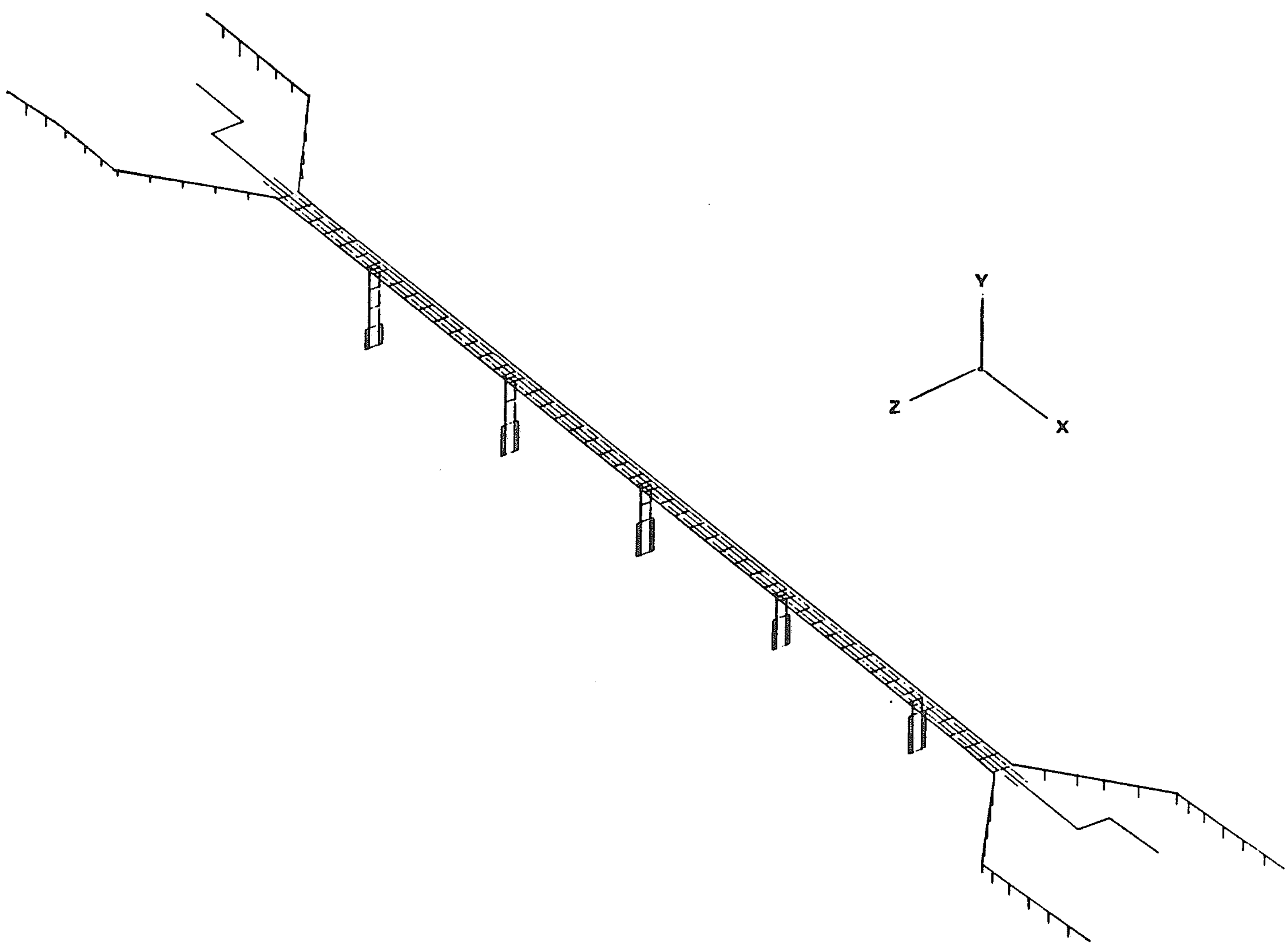


FIGURE 1

FIGURE 2

MODEL OF EXISTING DIAPHRAGMS

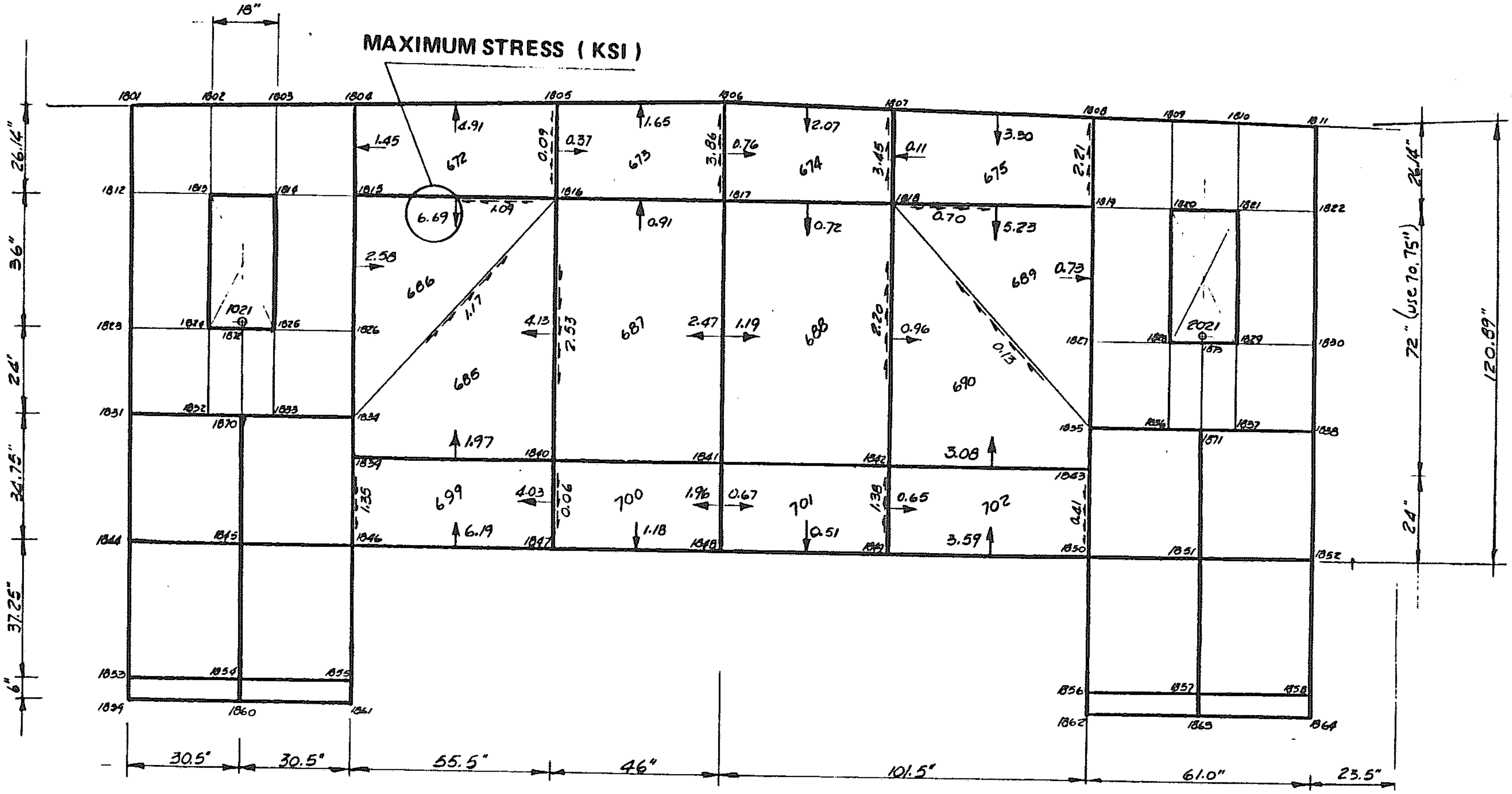


FIGURE 3

MODEL OF MODIFIED DIAPHRAGMS

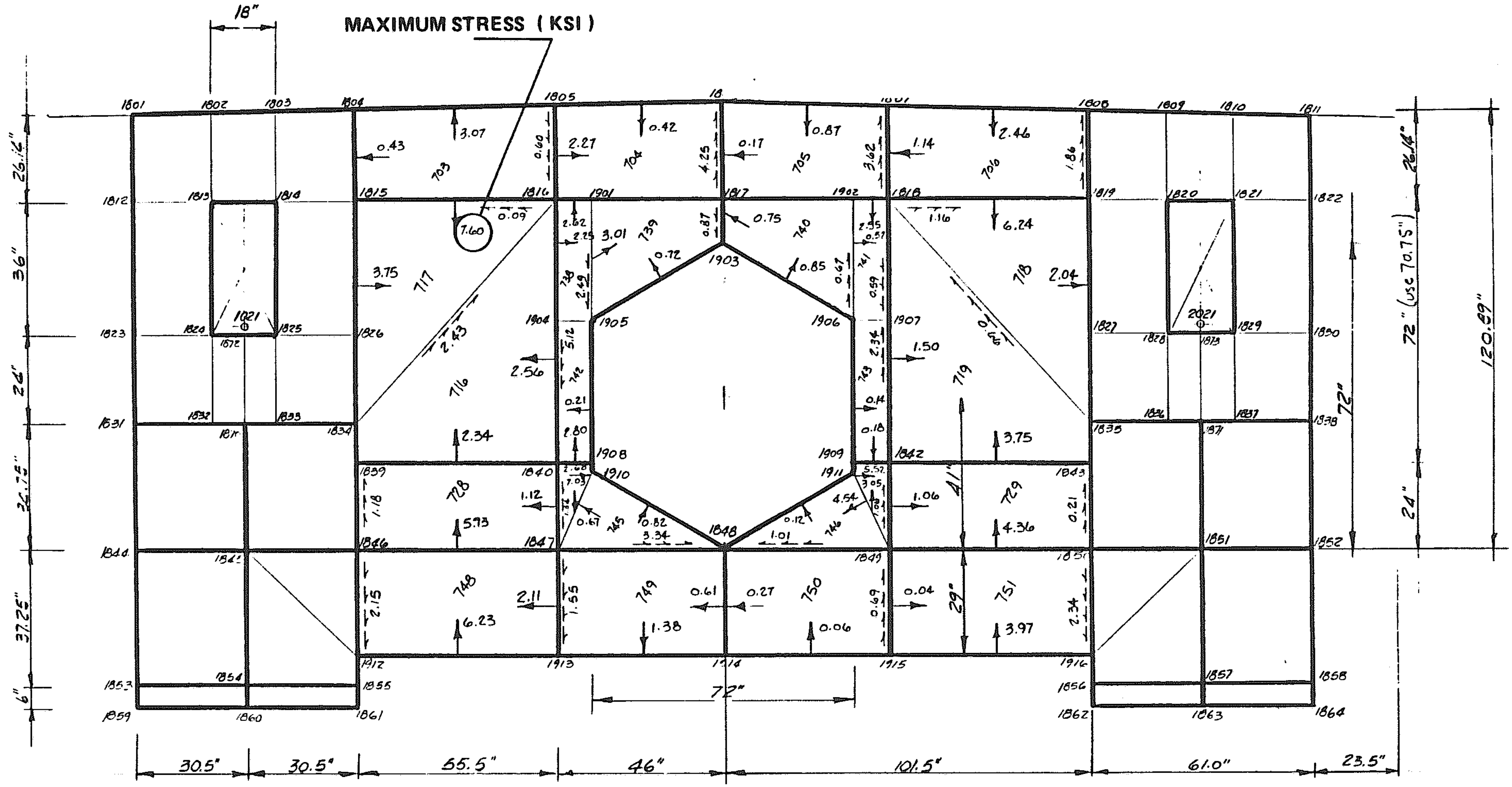
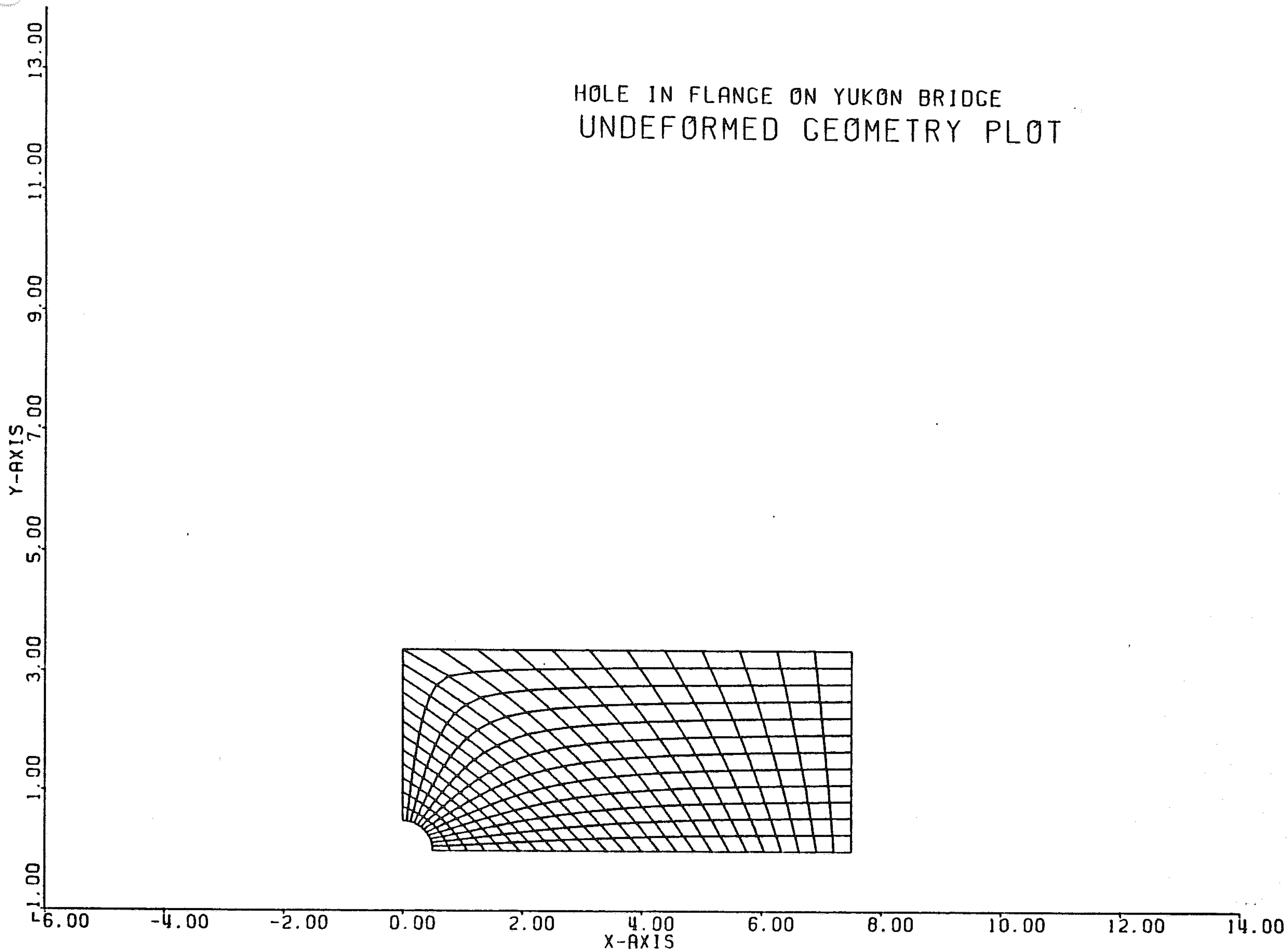


FIGURE 4

GAS PIPELINE ON THE YUKON RIVER BRIDGE
RESPONSE TO TECHNICAL CONCERNS



10.0 REFERENCES

1. "Joint Meeting in Seattle on April 1 and 2, 1982," letter from Robert N. Hauser to Messrs. C. E. Behlke, A. C. Mathews, and J. F. McPhail, April 13, 1982.

2. "Designing the Yukon River Bridge," by the State of Alaska Department of Highways Bridge Design Section, May, 1982.

3. "Recommended Design Loads for Bridges," by the Committee on Loads and Forces on Bridges of the Committee on Bridges of the Structural Division, ASCE ST7, July, 1981, pp. 1161-1213.

4. American Association of State Highways and Transportation Officials, Standard Specifications for Highway Bridges - 77 and interim addenda.

5. "Bridge Fatigue Guide," by Dr. John W. Fisher, American Institute of Steel Construction, New York, NY, 1977.

6. "Guide to Design Criteria for Bolted and Riveted Joints," by John W. Fisher and John Strick, John Wiley and Sons, New York, NY, 1974.

7. "High Strength Bolted Moment Connections," by Richard Douty and William McGuire, ASCE ST2, April, 1965, pp. 101-128.

8. "ANSYS User's Manual," by Gabriel DeSalvo and John Swanson, Houston, Penna, 1982.

9. "Impact Factors for Fatigue Design," by Charles Schilling, ASCE ST9, September, 1982, pp. 2034-2044.

10. "ASME Boiler and Pressure Vessel Code," Section VIII, July 1, 1980.

11. "Dynamics of Vibration," Enrico Volterra and E. R. Zachmanoglow, 1965, Charles E. Merrill Books, Columbus, Ohio.

12. "Introduction to Structural Dynamics," by John Biggs, McGraw Hill, 1964.

11.0 APPENDICES

APPENDIX A	Alaska Department of Transportation Correspondence
APPENDIX B	Drawings of Pipe Placement Design Alternatives
APPENDIX C	Calculation Sheets for Analysis of Proposed Diaphragm Modifications
APPENDIX D	Results of PSI Computer Study on Bolt Hole Configurations
APPENDIX E	Calculation Sheets for Analysis of Pipeline Fatigue
APPENDIX F	Calculation Sheets for Analysis of Effects of Postulated Hole in the Pipeline

APPENDIX A

ALASKA
DEPARTMENT OF TRANSPORTATION CORRESPONDENCE

GULF INTERSTATE ENGINEERING COMPANY
MICHAEL BAKER, JR., INC.
A Joint Venture

REPLY TO:
P. O. BOX 56228
1233 WEST LOOP SOUTH
HOUSTON, TEXAS 77027
(713) 960-0110
TELEX 79-4518

ALASKAN GAS PIPELINE PROJECT

MINUTES OF MEETING

Date: March 20, 1981
1:00 P.M.

Place: Alaska Department of Transportation
Douglas, AK

In Attendance:

John Santora	NWA - Fairbanks (451-1233)
Morris A. Fraley	NWA - Houston (960-0100 Ext. 174)
Lynn J. Harnish	AKDOT, Pipeline Coordinator's Office - Fairbanks (456-4835)
Donald Halsted	AKDOT, Chief Bridge Engineer - Douglas (364-3463)
Larry Carlson	AKDOT, Bridge Design - Douglas (364-2121
Dennis Nottingham	Paratrovich & Nottingham, Inc. (272-8491)
Robert H. Tilly	JV/Michael Baker, Jr., Inc. (452-1217)
Keith Meyer	JV/Michael Baker, Jr., Inc. (975-3468)
Frank J. Kempf	JV/Michael Baker, Jr., Inc. (233-6526)

Purpose of Meeting: To secure data from AKDOT on the design, construction, and present condition of the Yukon River Bridge.

1. Literature and Drawings - DOT handed Baker copies of:

   (a) Booklet - Designing the Yukon River Bridge - AKDOT 1972
   (b) Booklet - Foundation Report, Yukon River Crossing - AKDOT 1972
   (c) Booklet - Pier 4 Foundation Drilling, Summary - AKDOT 1975
   (d) Booklet - Yukon River Bridge Risk Analysis Criteria Development, Nottingham & Paratrovich - 1981
   (e) Drawings - Set of "As-Built" Bridge Construction Contract Plans

2. Bridge Design Calculations - AKDOT prefers not to release the bridge design calculations.

3. Structural Steel Shop Drawings - Due to the multitude of sheets, AKDOT will release copies of specific sheets when so requested.

4. Present Condition of the Bridge - AKDOT reports the bridge has been inspected every two years. AKDOT says that the bridge, including Pier 4, has not experienced any structural problems to date. Accordingly, the as-built construction plans reflect the present condition of the bridge.

GULF INTERSTATE ENGINEERING COMPANY MICHAEL BAKER, JR., INC.

A Joint Venture

REPLY TO:
P. O. BOX 56228
1233 WEST LOOP SOUTH
HOUSTON, TEXAS 77027
(713) 960-0110
TELEX 79-4518

5. Bridge Roadway Surface - AKDOT's present and future plans are to periodically repair and maintain the present timber roadway surface. AKDOT does not intend, in the future, to exceed the 30 P.S.F. allowance for bridge roadway surface as shown on the contract plans.

6. Protective Roof Cover over Oil Pipeline on Bridge - AKDOT reports that this cover, installed subsequent to the completion of the bridge, weighs 165 pounds per lineal foot.

7. Vehicular Overloads (by Permit) - AKDOT reports they permit a 35 to 40% overstress (above the elastic design allowables) for the occasional passage over the bridge of vehicular overloads operating under permit.

8. AASHTO Bridge Design Live Load - AKDOT has no plans to increase the present design live load of the HS20 truck and/or equivalent lane loading. Also, for such vehicular loadings, AKDOT prefers no bridge members be overstressed but will tolerate a 5% overstress. Good engineering judgment and practice should dictate.

9. Current Traffic Usage of the Bridge - AKDOT reports that there are currently approximately 100 vehicles traveling over the bridge each day. About 90% are trucks and 10% are light vehicles. It was recommended that Mr. John Martin of AKDOT in Fairbanks be contacted to obtain more accurate traffic statistics. Also, AKDOT feels that the traffic volume will at least double in the immediate future with the impending construction of the gas pipeline.

10. Traffic Delays During Bridge Construction - Should there be gas pipeline construction on the bridge in the future, any interruption to the normal flow of vehicular traffic due to construction will have to be approved by AKDOT. AKDOT feels that occasional delays of an hour or two are tolerable but a one-day delay (for example) is intolerable. The use of a detour and ice bridge to avoid long delays may be acceptable.

These minutes were prepared by Frank J. Kempf.

JAY S. HAMMOND, GOVERNOR

DEPARTMENT OF TRANSPORTATION AND PUBLIC FACILITIES
Division of Highway Design & Construction

P. O. BOX 1467
JUNEAU, ALASKA 99802

364-2121 Ext. 240

March 24, 1981

242H

Re: Pipe Forces on Bridge.

Mr. John Santora
Manager, Government Affairs, Alaska
Northwest Alaska Pipeline Company
701 Douglas Avenue
Fairbanks, Alaska 99701

Dear Mr. Santora:

In response to the request of your Consultants expressed in last Friday's meeting here in Juneau, please find enclosed a table of pipeline forces on the Yukon River Bridge. Your Consultants may use these values as shown for their analyses.

The Consultants also requested a copy of any foundation information we had on proposed Yukon River crossings other than the site of the existing bridge. Unfortunately we were unable to locate any in our files. Perhaps Alyeska would have such information in their records.

If we can be of any more assistance, please give us a call.

Very truly yours,

D. E. Halsted
Chief Bridge Engineer

Enclosure:

		PIPE FORCES ON BRIDGE					
VERTICAL F	F_{YDL}	48k	48k	48k	48k	48k	50k
	F_{YEQ}	±30k	±30k	±30k	±40k	±30k	±30k
HORIZONTAL F	F_X	15k	15k	15k	15k	15k	15.5k
	F_Z	10k	10k	10k	10k	10k**	0k
	F_{XEQ}	15k	15k	15k	15k	15k	180k*
	F_{ZEQ}	20k	20k	20k	70k	20k	20k
		TYPE 1 NODES 22-25	TYPE 2 NODES 71-74	TYPE 3 NODES 26-28 68-70	TYPE 4 NODES 29-30 66-67	TYPE 4 NODES 31-47 49-65	TYPE 5 NODE 48 ANCHOR

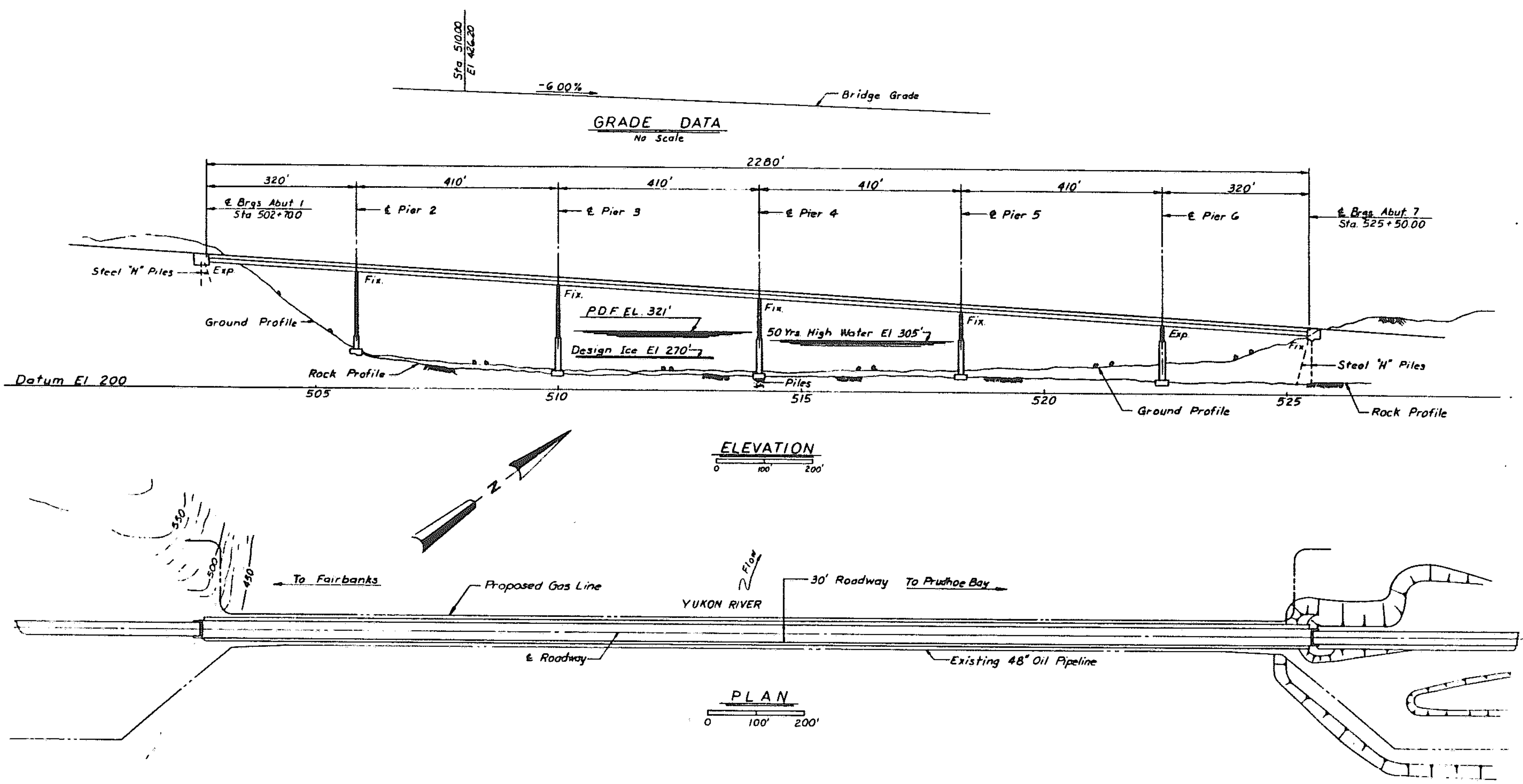
* ANCHOR DESIGNED TO SLIP AT 125 K.

** 21 KIPS AT NODES 31 & 65, 10K AT ALL OTHERS.

LOAD DATA FOR ONE SIDE OF BRIDGE			
ITEM	WEIGHT	SIZE	REMARKS
PIPE & OIL	1000 #/L.F.	48" O.D. + 8" INSUL.	PIPE, OIL & INSULATION
2-3" ϕ CONDUIT	14.0 #/L.F.	3.5" O.D.	10 FOOT LENGTH
———	3.0 #/L.F.	3.87" O.D. X 3.25"	COUPLINGS - 10' C.T.C. SPAC.
———	2.0 #/L.F.	———	6 - #6 CABLES
PIVOT SLIDE SHOE	1000 # EA.	SEE DWG.	SPACING VARIES (33 REQ'D)
ANCHOR	5400 # EA.	SEE DWG.	MID SPAN, ABOVE PIER

APPENDIX B

DRAWINGS OF
PIPE PLACEMENT
DESIGN ALTERNATIVES



FLUOR
PROJECT MANAGEMENT CONTRACTOR

ALASKAN NORTHWEST NATURAL GAS TRANSPORTATION COMPANY

YUKON RIVER BRIDGE STUDY

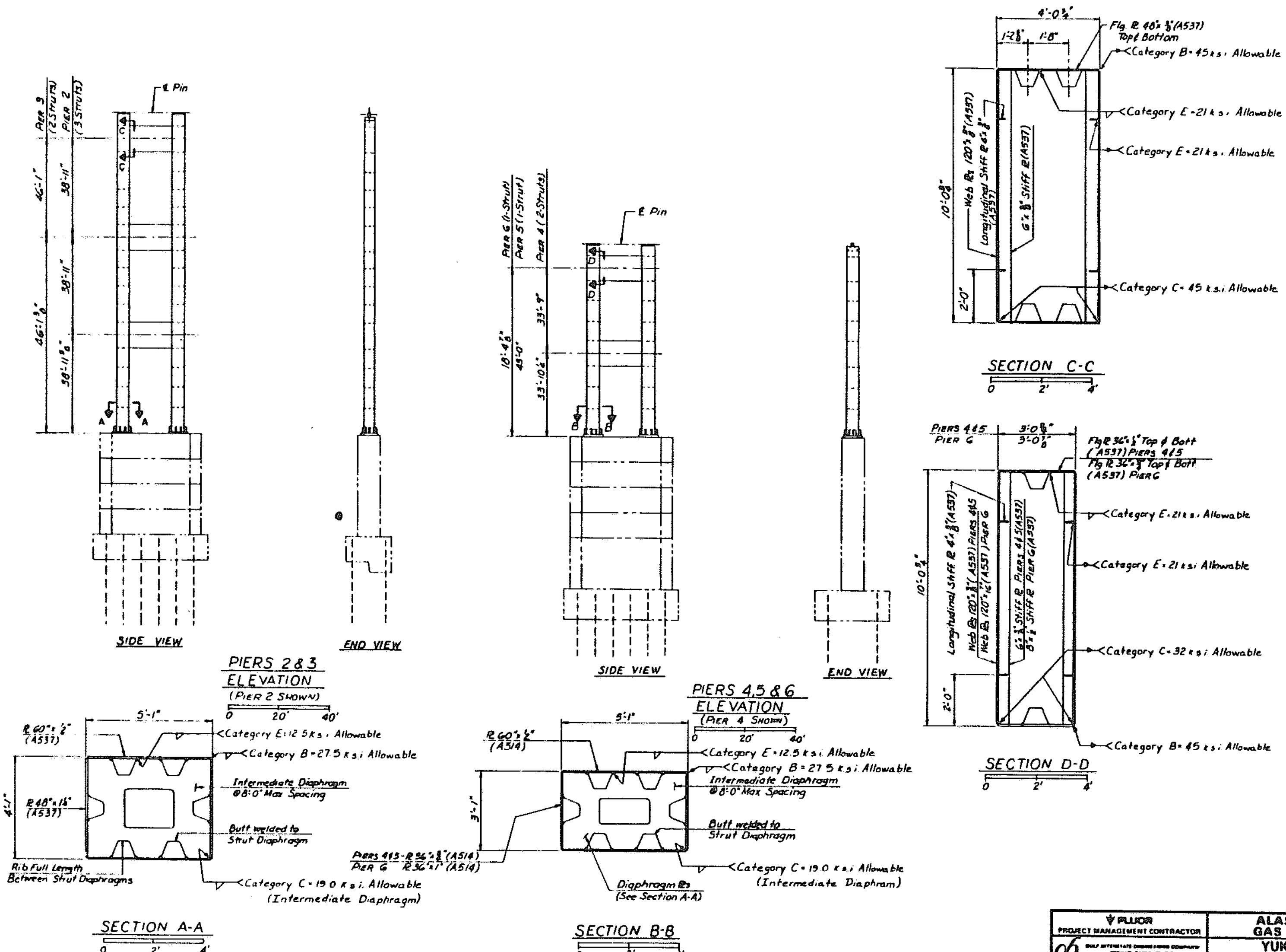
CIVIL CONSTRUCTION

PLAN AND ELEVATION

AT MP. 361.5

ALASKA SEGMENT OF THE ALASKAN NATURAL GAS TRANSPORTATION SYSTEM

SCALE IN FEET	DRAWING NUMBER	REV
AS NOTED	4680-13-11-W-SK-064A	0



GENERAL NOTES

- This drawing shows the locations of pier fatigue critical details and gives the allowable stress range at these details.
- Allowable fatigue stress range values in Pier Columns are obtained from 1977 AASHTO Specifications Table 1.7.2 A1, Thru 1980 Interim Specifications for Non-Redundant Load Path Structures. Allowable fatigue stress range values in Pier Struts are obtained from Table 1.7.2.A1 for Redundant Load Path Structures.

REFERENCE DRAWINGS

FLUOR
PROJECT MANAGEMENT CONTRACTOR

ALASKAN NORTHWEST NATURAL GAS TRANSPORTATION COMPANY

YUKON RIVER BRIDGE STUDY

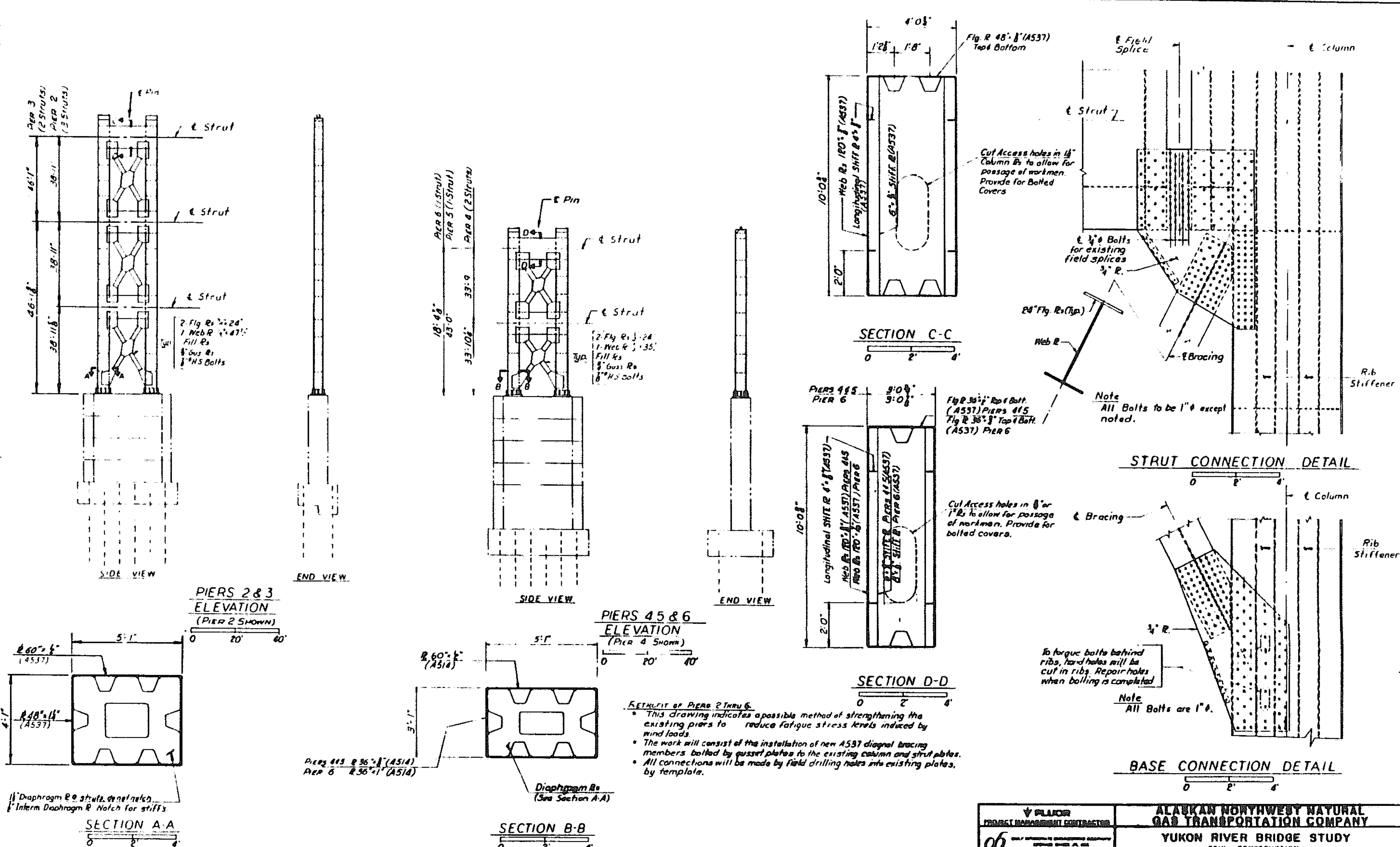
CIVIL CONSTRUCTION

FATIGUE STRESS - PIERS 2 THRU 6

AT MP. 361.5

ALASKA SEGMENT OF THE ALASKA NATURAL GAS TRANSPORTATION SYSTEM

SCALE IN FEET	DRAWING NUMBER	REV.
AS NOTED	4680-13-11-W-SK-0646	0



RETROFIT OF PIERS 2 THRU 6.

- This drawing indicates a possible method of strengthening the existing piers to reduce fatigue stress levels induced by wind loads.
- The work will consist of the installation of new A537 diagonal bracing members bolted by gusset plates to the existing column and strut plates.
- All connections will be made by field drilling holes into existing plates, by template.

NOTES

- All new structural steel plates and built up members shall be ASTM A537 Grade A
- All connections shall be made with A325 High Strength Bolts

FLUOR
PROJECT MANAGEMENT CONTRACTOR

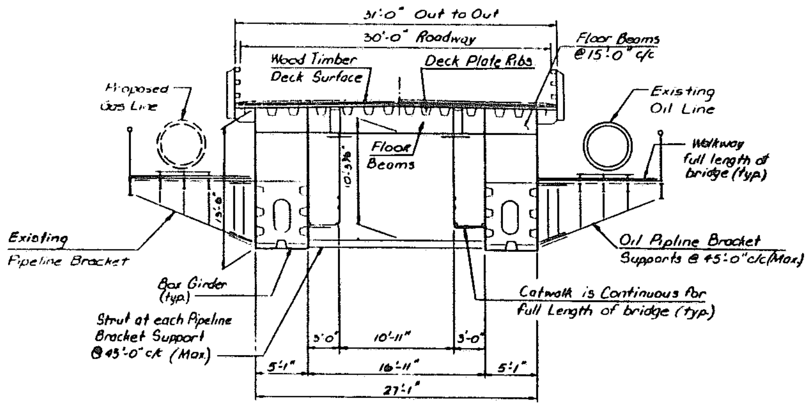
ALASKAN NORTHWEST NATURAL GAS TRANSPORTATION COMPANY

YUKON RIVER BRIDGE STUDY
CIVIL CONSTRUCTION
RETROFIT OF PIERS 2 THRU 6
AT MP. 361.5

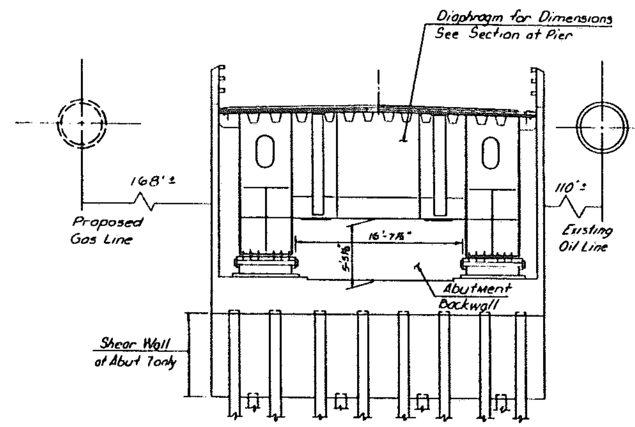
ALASKA SEGMENT OF THE ALASKA NATURAL GAS TRANSPORTATION SYSTEM

SCALE IN FEET	NUMBER	REV
AS NOTED	4680-13-11-W-SK-084H	0

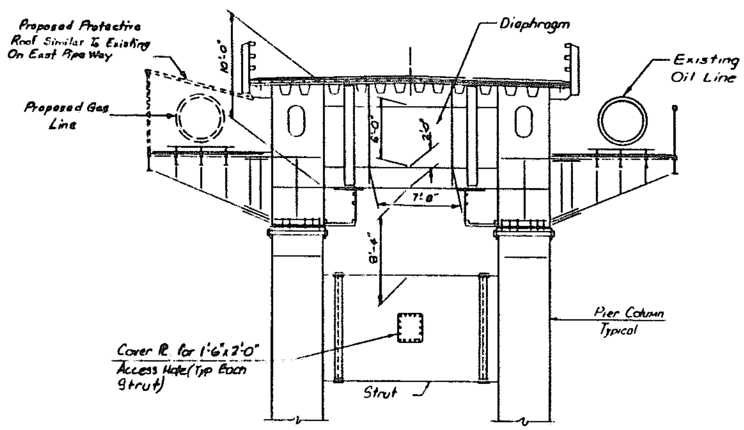
ALTERNATIVE A



TYPICAL SECTION AT OIL & GAS PIPELINE SUPPORT



TYPICAL SECTION AT ABUTMENT
(Abutment 7 Shown)



TYPICAL SECTION @ PIER
(Total of 5 Piers)

GENERAL NOTES

REFERENCE DRAWINGS

NOTES	DATE	REVISION	APP	DWG NO	REFERENCE DRAWING
				MICROFILM NO	

FLUOR
PROJECT MANAGEMENT CONTRACTOR

ALASKAN NORTHWEST NATURAL GAS TRANSPORTATION COMPANY
YUKON RIVER BRIDGE STUDY
CIVIL CONSTRUCTION
EXISTING CROSS SECTIONS
AT MP. 361.5
ALASKA SEGMENT OF THE ALASKAN NATURAL GAS TRANSPORTATION SYSTEM

SCALE IN FEET	DRAWING NUMBER	REV
AS NOTED	4680-13-11-W-SK-064B	0

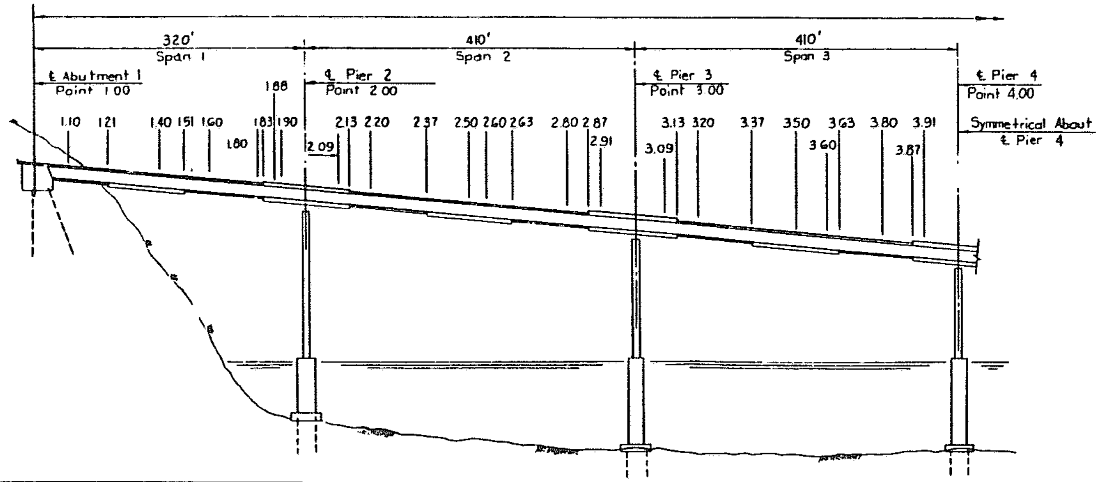
RELATIVE STRESSES IN SUPERSTRUCTURE

Element	1.10	1.21	1.40	1.51	1.60	1.80	1.83	1.88	1.90	2.00	2.09	2.13	2.20	2.37	2.50
Deck Plate	0.25	0.49	0.61	0.58	0.44	0.40	0.48	0.51	0.53	0.91	0.46	0.44	0.20	0.58	0.65
Bottom Flange	0.43	0.85	0.86	0.99	0.76	0.68	0.81	0.89	0.92	0.85	0.82	0.44	0.34	0.99	0.90

Element	2.60	2.63	2.80	2.87	2.91	3.00	3.09	3.13	3.20	3.37	3.50	3.60	3.63	3.80	3.87	3.91	4.00
Deck Plate	0.58	0.58	0.45	0.52	0.54	0.96	0.85	0.88	0.49	0.94	0.65	0.58	0.57	0.19	0.51	0.59	0.95
Bottom Flange	0.81	0.99	0.77	0.89	0.52	0.90	0.77	0.51	0.28	0.57	0.90	0.80	0.98	0.32	0.86	0.93	0.90

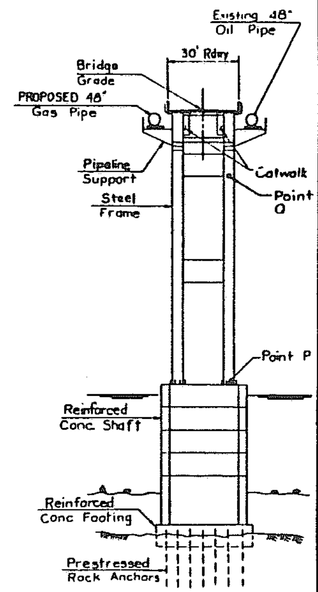
GENERAL NOTES

1) THE STRESSES SHOWN ON THIS SHEET ARE FOR THE EXISTING BRIDGE PRIOR TO ANY CONTEMPLATED STRENGTHENING
2) RELATIVE STRESS IS DEFINED AS THE RATIO OF THE ACTUAL STRESS TO THE ALLOWABLE STRESS WITH AN INCREASE IN THE ALLOWABLE STRESS FOR GROUP LOADING
3) STRESSES AT POINTS P AND Q ARE BASED ON THE INTERACTION FORMULA FOR MEMBERS LOADED AXIALLY AND IN BENDING
4) STEEL FRAMES 2 THRU 5 HAVE FIXED SUPPORTS AT POINT P AND STEEL FRAME 6 HAS A HINGED SUPPORT AT POINT P – IN BOTH LATERAL AND LONGITUDINAL DIRECTIONS



PARTIAL ELEVATION

No Scale



TYPICAL SECTION

No Scale

Looking Ahead Stations

RELATIVE STRESSES AT POINT P AND Q

Pier	Group	I	II	IV	Va	Vb	VII*	VII**
	Allowable	1.0	1.25	1.25	1.40	1.40	1.33	1.62
2	Q	0.59	0.48	0.39	0.39	0.36		
	P	0.53	0.85	0.30	0.87	0.93		0.94
3	Q	0.55	0.44	0.37	0.33	0.34	NOT CRITICAL	
	P	0.51	0.89	0.76	0.94	0.98		0.94
4	Q	0.44	0.35	0.29	0.29	0.26		
	P	0.39	0.53	0.51	0.60	0.64		0.57
5	Q	0.38	0.31	0.26	0.27	0.27		
	P	0.34	0.57	0.52	0.55	0.64		0.75
6	Q	0.32	0.38	0.22	0.29	0.36	–	0.28
	P	–	–	–	–	–		–

* AASHTO Specified Earthquake Criteria

** NWA Contingency Earthquake

GROUP LOADS

I - Dead + Live + Impact
II - Dead + Wind 80
IV - Group I + Temp 80
Va - Dead + Wind 60 + Temp. 80
Vb - Dead + Wind 80 + Temp. 40
VII - Dead + Earthquake

Temp 80 = +100°F to -60°F
Temp 60 = +80°F to -40°F
Temp 40 = +60°F to -20°F
Erection Temp = +20°F
Wind 80 = 50 PSF (80 MPH)
Wind 60 = 25 PSF (60 MPH)

REFERENCE DRAWINGS

FLUOR
PROJECT MANAGEMENT CONTRACTOR

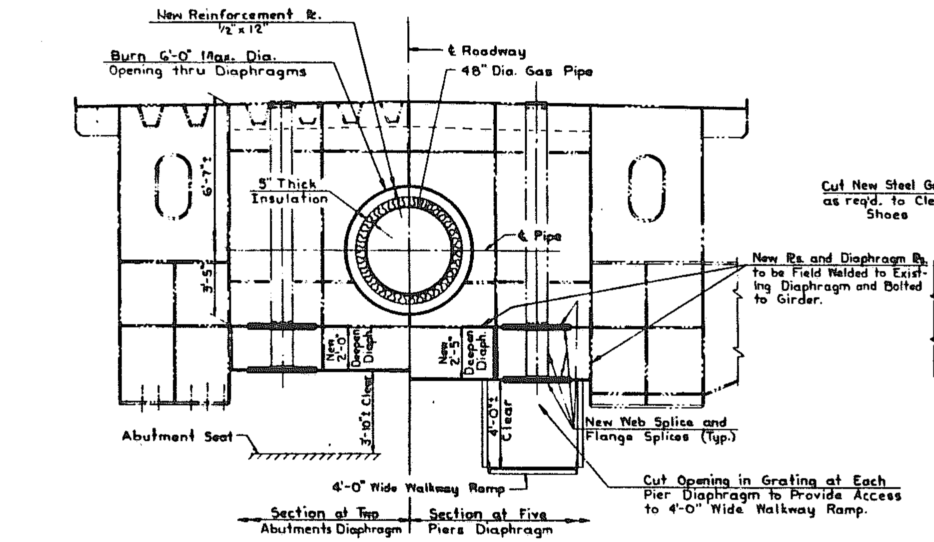
ALASKAN NORTHWEST NATURAL GAS TRANSPORTATION COMPANY

YUKON RIVER BRIDGE STUDY
CIVIL CONSTRUCTION
STRESS TABLES
AT MP. 361.5

ALASKA SEGMENT OF THE ALASKAN NATURAL GAS TRANSPORTATION SYSTEM

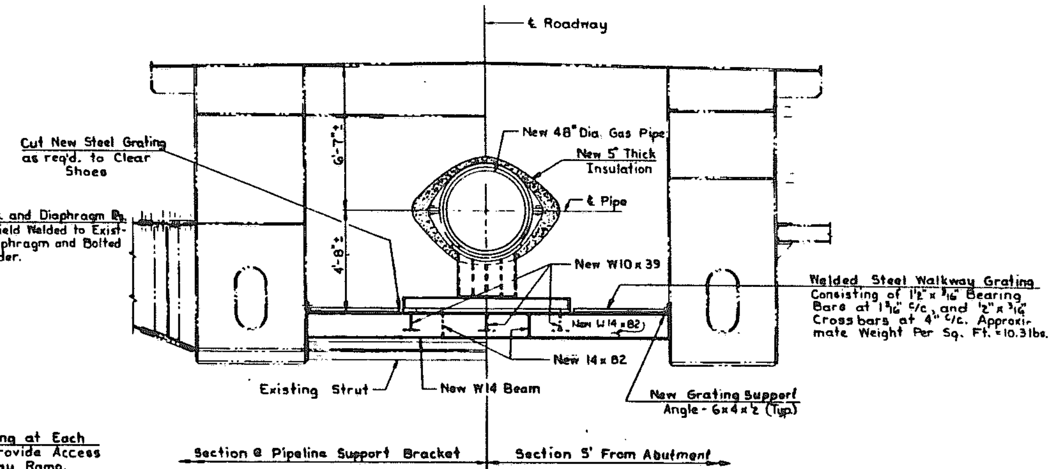
Scale	Drawing Number	Rev.
AS NOTED	4680-13-11-W-SK-064C	0

ALTERNATIVE B



DIAPHRAGM MODIFICATIONS

0 4' 8'

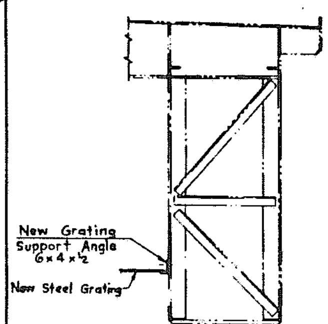


TYPICAL SECTION SHOWING GAS LINE SUPPORT

0 4' 8'

INSTALLATION OF GAS LINE SUPPORTS ON BRIDGE

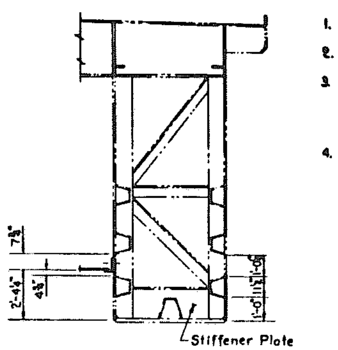
1. Establish One Way Traffic on the Bridge to Facilitate Construction.
2. Reinforce Diaphragms at the Abutments and over the Piers.
3. Install New Gas Line Support Beams and Walkway Support Beams between the Box Girders using High Strength Bolts for the Connections. Remove the Existing Catwalks and Install the New Maintenance Grating.
4. Cut Openings thru the Diaphragm Webs and Reinforce the Edges of the Plates.



SECTION D-D

TYPICAL SECTION @ FLOOR BEAMS

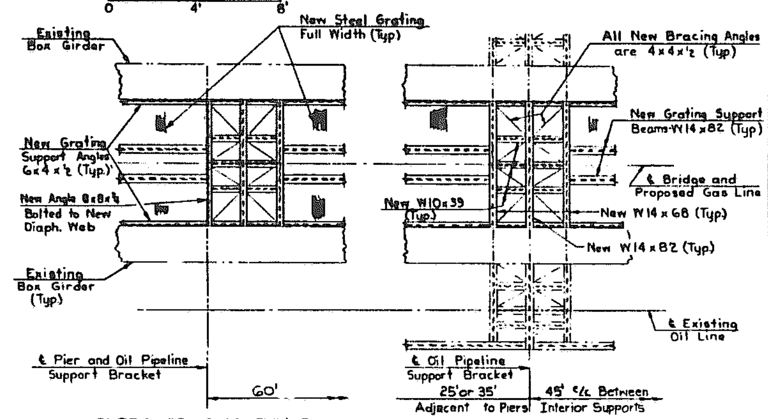
0 4' 8'



SECTION E-E

TYPICAL SECTION @ FLOOR BEAM, NEAR PIERS

0 4' 8'



SUPPORTS AT ABUTMENT
(2 LOCATIONS)

INTERMEDIATE SUPPORT
(48 Locations)

GAS LINE SUPPORT BEAMS

PRELIMINARY

Note
For Location of Sections D-D and E-E see Figure no. 7.

NOTES
- Fabricated Structural Steel A537, Grade A.
- High Strength Bolts - A325.

REV	DATE	REVISION
A	4/1/81	Typical Section Showing Gas Line Support - Revised

FLUOR
PROJECT MANAGEMENT CONTRACTOR

ALASKAN NORTHWEST NATURAL GAS TRANSPORTATION COMPANY

YUKON RIVER BRIDGE STUDY
CIVIL CONSTRUCTION
ALT. I GAS LINE SUPPORT DETAILS
AT MP 361.5

ALASKA SEGMENT OF THE ALASKA NATURAL GAS TRANSPORTATION SYSTEM

SCALE	DRAWING NUMBER	REV
NTS	4680-13-11-W-SK-064J	A

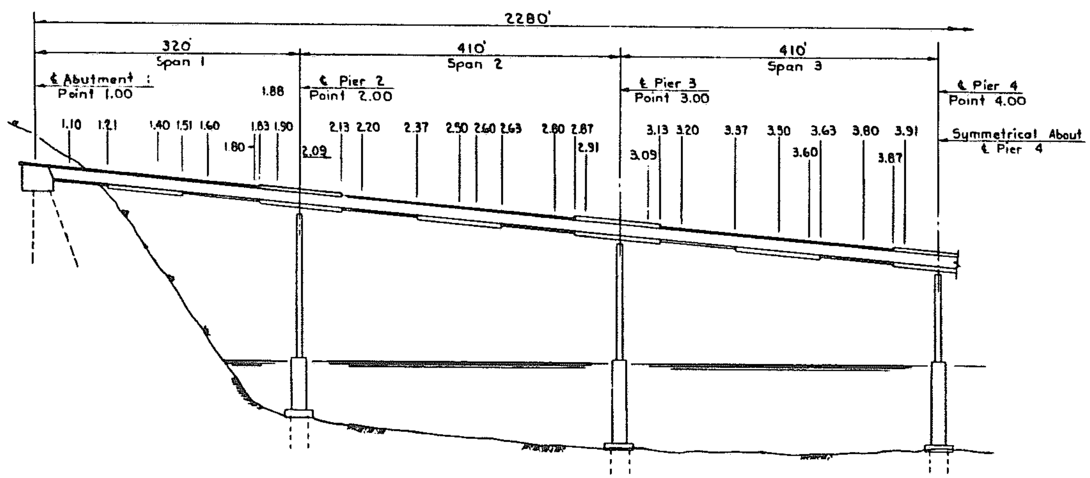
RELATIVE STRESSES IN SUPERSTRUCTURE

Case	Element	Location 1.10	1.21	1.40	1.51	1.60	1.80	1.83	1.88	1.90	2.00	2.09	2.13	2.20	2.37
1	Deck Plate	0.32	0.56	0.63	0.62	0.46	0.35	0.49	0.51	0.53	0.97	0.50	0.47	0.16	0.59
	Bottom Flange ℄	0.54	0.98	0.90	1.09	0.81	0.62	0.86	0.91	0.51	0.93	0.90	0.83	0.28	1.04
2	Deck Plate	0.33	0.62	0.72	0.67	0.51	0.39	0.53	0.53	0.60	1.03	0.54	0.51	0.16	0.63
	Bottom Flange ℄	0.59	1.08	1.05	1.17	0.90	0.68	0.92	0.95	0.58	0.99	0.97	0.90	0.28	1.11

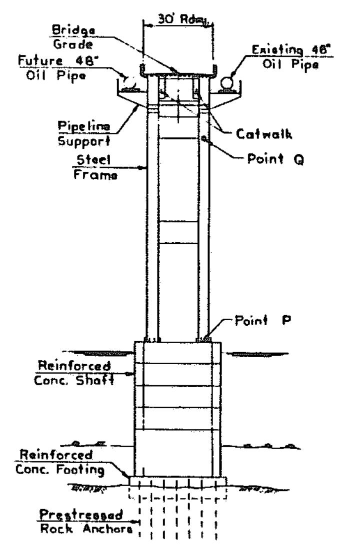
Case	Element	Location 2.50	2.60	2.63	2.80	2.87	2.91	3.00	3.09	3.13	3.20	3.37	3.50	3.60	3.63	3.80	3.87	3.91	4.00
1	Deck Plate	0.67	0.59	0.60	0.21	0.53	0.54	1.00	0.54	0.52	0.21	0.59	0.67	0.60	0.60	0.19	0.54	0.54	1.01
	Bottom Flange ℄	0.95	0.85	1.05	0.38	0.94	0.97	0.96	0.96	0.92	0.37	1.04	0.96	0.86	1.05	0.34	0.94	0.96	0.97
2	Deck Plate	0.72	0.64	0.64	0.22	0.59	0.58	1.07	0.58	0.58	0.21	0.64	0.75	0.65	0.64	0.21	0.58	0.58	1.08
	Bottom Flange ℄	1.03	0.92	1.12	0.38	1.03	1.04	1.05	1.04	1.01	0.37	1.12	1.04	0.93	1.13	0.36	1.02	1.04	1.04

Case 1 - Gas Pipeline plus One Oil Pipeline plus 2 inch Asphaltic Wearing Surface.

Case 2 - Gas Pipeline plus Two Oil Pipelines plus 2 inch Asphaltic Wearing Surface.



PARTIAL ELEVATION
No Scale



TYPICAL SECTION
No Scale
Looking Ahead Stations

Notes

- The Stresses shown on this Sheet are for the Existing Bridge prior to any Contemplated Strengthening; said Stresses relate to Cases 1 and 2 Loadings described above.
- Relative Stress is defined as the Ratio of the Actual Stress to the Allowable Stress with an increase in the Allowable Stress for Group Loading.
- Stresses at Points P and Q are based on the Interaction Formula for Members Loaded Axially and in Bending.
- Steel Frames 2 thru 5 have Fixed Supports at Point P and Steel Frame 6 has a Hinged Support at Point P - in both Lateral and Longitudinal Directions.

RELATIVE STRESSES AT POINT P

Pier	Group	I	II	IV	Va	Vb	VII*	VIIa*	VIIb*
	Case / Allowable	1.0	1.25	1.25	1.40	1.40	1.33	1.67	1.83
2	1	.56	1.08	1.06	1.12	1.11	.92	1.10	1.12
	2	.54	.90	1.04	1.10	1.09	.98	1.16	1.16
3	1	.51	.90	1.04	1.10	1.09	1.00	1.17	1.19
	2	.50	.89	1.02	1.08	1.08	1.03	1.19	1.20
4	1	.41	.61	.70	.71	.71	.75	.82	.81
	2	.39	.59	.68	.69	.69	.78	.84	.84
5	1	.35	.55	.68	.69	.65	.79	.86	.85
	2	.34	.52	.68	.68	.64	.85	.89	.87
	AT POINT Q								
6	1	.29	.37	—	.33	.33	.93	.74	.68
	2	.27	.36	—	.32	.32	.99	.79	.72

Group Loads

I - Dead + Live + Impact
II - Dead + Wind 80
IV - Group I + Temp. 80
Va - Dead + Wind 60 + Temp. 80
Vb - Dead + Wind 80 + Temp. 40
VII - Dead + Earthquake
VIIa - Dead + Earthquake + Temp. 60
VIIb - Dead + Earthquake + Temp. 80
Earthquake - Operation (2% Dampening $\mu = 1.5$)

Wind 80 = 50 PSF (80 M.P.H)
Wind 60 = 25 PSF (60 M.P.H.)

Temp. 80 = +100° F. to -60° F.
Temp. 60 = +80° F. to -40° F.
Temp. 40 = +60° F. to -20° F.
Erection Temp. = +20° F.

* Denotes transverse earthquake only. Longitudinal earthquake was not critical.

PRELIMINARY

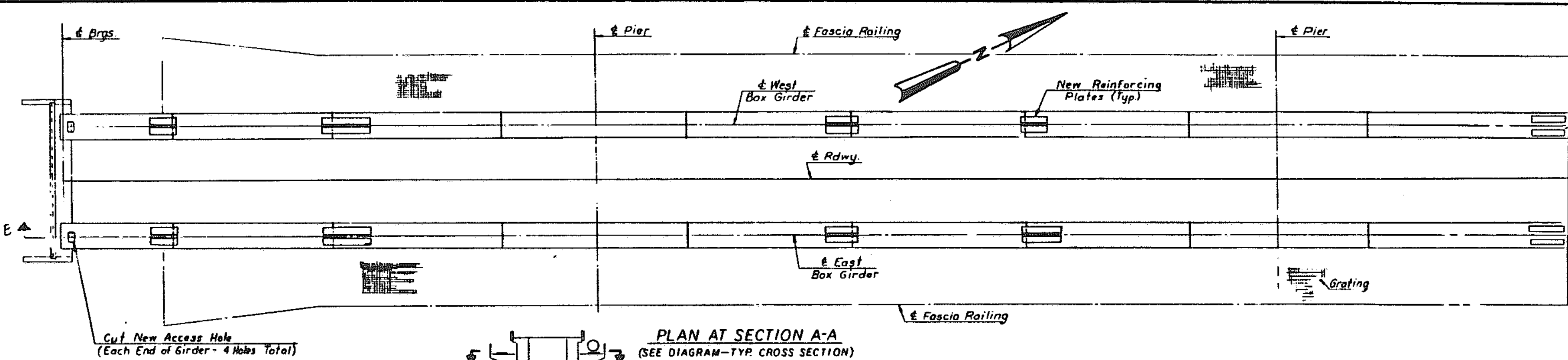
Rev. No.	Date	Revision
A	4/1/81	Relative Stresses In Superstructure Revised

FLUOR
PROJECT MANAGEMENT CONTRACTOR

ALASKAN NORTHWEST NATURAL GAS TRANSPORTATION COMPANY

YUKON RIVER BRIDGE STUDY
CIVIL CONSTRUCTION
ALT. I STRESS TABLES
AT MP 361.5
ALASKA SEGMENT OF THE ALASKA NATURAL GAS TRANSPORTATION SYSTEM

Scale: NTS
Drawing Number: 4680-13-11-W-SK-064C
Rev: A

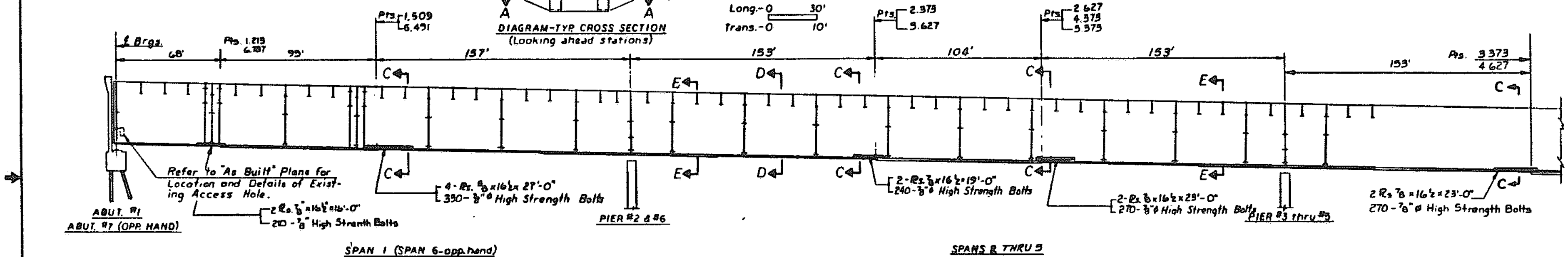


PLAN AT SECTION A-A

(SEE DIAGRAM–TYP. CROSS SECTION)

Long.-0 30'
Trans.-0 10'

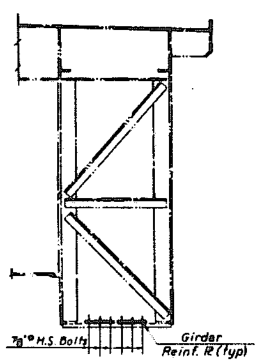
DIAGRAM-TYP CROSS SECTION
(Looking ahead stations)



SECTION : B-B

WEST GIRDER SIMILAR

HORIZ.-0 30'
VERT.-0 10'



SECTION C-C

no scale

PROCEDURE TO STRENGTHEN BOX GIRDERS

- At the locations shown above, place and bolt new steel plates to the bottom flange plates of the box girders.
- Use high strength bolts in attaching the new plates to the existing bottom flange plates.
- To allow movement of materials into the box girders, cut a maximum of four access holes thru the deck, near the abutments.

PRELIMINARY

NOTES

- Reinf. Pls shall be ASTM A537 Grade A Steel.
- 7/8" ø High Strength Bolts shall be ASTM A325.
- For SECTIONS D-D, E-E; See Figure No. 6

REV. NO.	DATE	REVISION
A	1/??/80	Reinforcing Plates - Revised

FLUOR PROJECT MANAGEMENT CONTRACTOR

ALASKAN NORTHWEST NATURAL GAS TRANSPORTATION COMPANY

YUKON RIVER BRIDGE STUDY

CIVIL CONSTRUCTION

ALT. I STRENGTHENING OF BOX GIRDERS AT MP 361.5

ALASKA SEGMENT OF THE ALASKA NATURAL GAS TRANSPORTATION SYSTEM

SCALE	DRAWING NUMBER	REV
NTS	4680-13-11-W-SK-064K	A

APPENDIX C

CALCULATION SHEETS
ANALYSIS OF PROPOSED
DIAPHRAGM MODIFICATIONS

GULF INTERSTATE ENGINEERING COMPANY — MICHAEL BAKER, JR., INC.

A Joint Venture

TASK NO. 52 TASK TITLE SPECIAL DESIGN & DETAILS - YUKON RIVER BRIDGE

SUBJECT STRENGTHENED DIAPHRAGM ANALYSIS SHEET NO. 1 OF 1

ANALYSIS - INDEX OF COMPUTATIONS FILE NO. 600

REV. NO. 0 BY LE DATE 3/25/82 CHKD. BY EU DATE 3/25/82

Appd [illegible]

GULF INTERSTATE ENGINEERING COMPANY — MICHAEL BAKER, JR., INC.

A Joint Venture

TASK NO. 52 TASK TITLE SPECIAL DESIGN & DETAILS - YUKON RIVER BRIDGE

SUBJECT STRENGTHENED DIAPHRAGM ANALYSIS SHEET NO. 1 OF 60

ANALYSIS · COMPUTER MODEL FILE NO. 600

REV. NO. 0 BY EU DATE 3/25/82 CHKD. BY LE DATE 3/25/82

ANALYSIS

OF

EXISTING COMPUTER MODELS

Form-JVE-2

FM-91-A-002

THE DIAPHRAGM STUDY IS CENTERED AROUND INVESTIGATING THE STRESSES IN ONE OF THE DIAPHRAGMS OF THE YUKON RIVER BRIDGE. THE DIAPHRAGM CHOOSEN FOR INVESTIGATION UNDER THIS STUDY IS LOCATED AT PIER #6. THE CHOICE OF PIER #6 WAS BASED ON A COMARRISON OF THE FIVE PIER DIAPHRAGM MOMENTS AND FORCES FROM THE CN1A COMPUTER MODEL (EXISTING YUKON RIVER BRIDGE + EXISTING OIL LINE).

UNDER THIS STUDY THE BRIDGE WAS SUBJECTED TO TWO LOADINGS. THE FIRST LOAD CONSISTS OF AN AASHTO LANE LOAD PLACED IN THE EAST LANE OF THE EXISTING BRIDGE WITH THE EXISTING OIL LINE AND EXISTING DIAPHRAGMS. THIS CONDITION WAS MODELED USING THE ANSYS FINITE ELEMENT COMPUTER PROGRAM. THE INPUT MODEL FOR THE PROGRAM WAS CN1ADPH1. THE SECOND LOAD CONSISTS OF AN AASHTO LANE LOAD PLACED IN THE EAST LANE OF THE EXISTING BRIDGE CONTAINING THE EXISTING OIL LINE, THE GAS LINE LOCATED BETWEEN THE BOX GIRDERS, AND THE MODIFIED DIAPHRAGMS TO ALLOW GAS LINE CONSTRUCTION. THE INPUT MODEL FOR THIS LOADING WAS CN3A1DPH.

GULF INTERSTATE ENGINEERING COMPANY — A Joint Venture — MICHAEL BAKER, JR., INC.

TASK NO. 52 TASK TITLE SPECIAL DESIGN & DETAILS - YUKON RIVER BRIDGE

SUBJECT STRENGTHENED DIAPHRAGM ANALYSIS

ANALYSIS - COMPUTER MODEL

FILE NO. 600

REV. NO. 0 BY LE DATE 3/22/82 CHKD. BY EU DATE 3/22/82

MOMENTS AND FORCES FROM CN1A MODEL

EXISTING YUKON RIVER BRIDGE + EXISTING OIL LINE

DIAPHRAGM NODES	Fx	Fy	Fz	Mx	My	Mz
1021	-35.11	212.32	18.75	1739.08	-6497.42	33,953.7
2021 PIER #6	35.11	-204.65	-18.29	-1739.08	1607.82	21085.9
1051	-32.26	197.62	15.47	-371.03	-6242.17	32497.4
2051 PIER #5	32.26	-189.96	-15.01	371.03	2219.46	18663.1
1081	-22.14	212.83	5.41	-66.03	-1017.80	34956.9
2081 PIER #4	22.14	-207.09	-5.07	66.03	-365.61	20472.5
1111	-38.88	193.58	13.99	510.38	-5423.27	30797.9
2111 PIER #3	38.88	-185.91	-13.53	-510.38	1790.54	19295.7
1141	-45.07	185.08	17.95	-1925.12	-5884.12	29848.0
2141 PIER #2	45.07	-177.41	-17.49	1925.12	1207.12	17999.7

CNIADPHI

COMPUTER MODEL

COMPUTER MODEL TO DETERMINE THE STRESS IN THE DIAPHRAGM AT PIER 6 : CN1ADPH1

MODEL CN1ADPH1 IS MODIFIED FROM CN1A

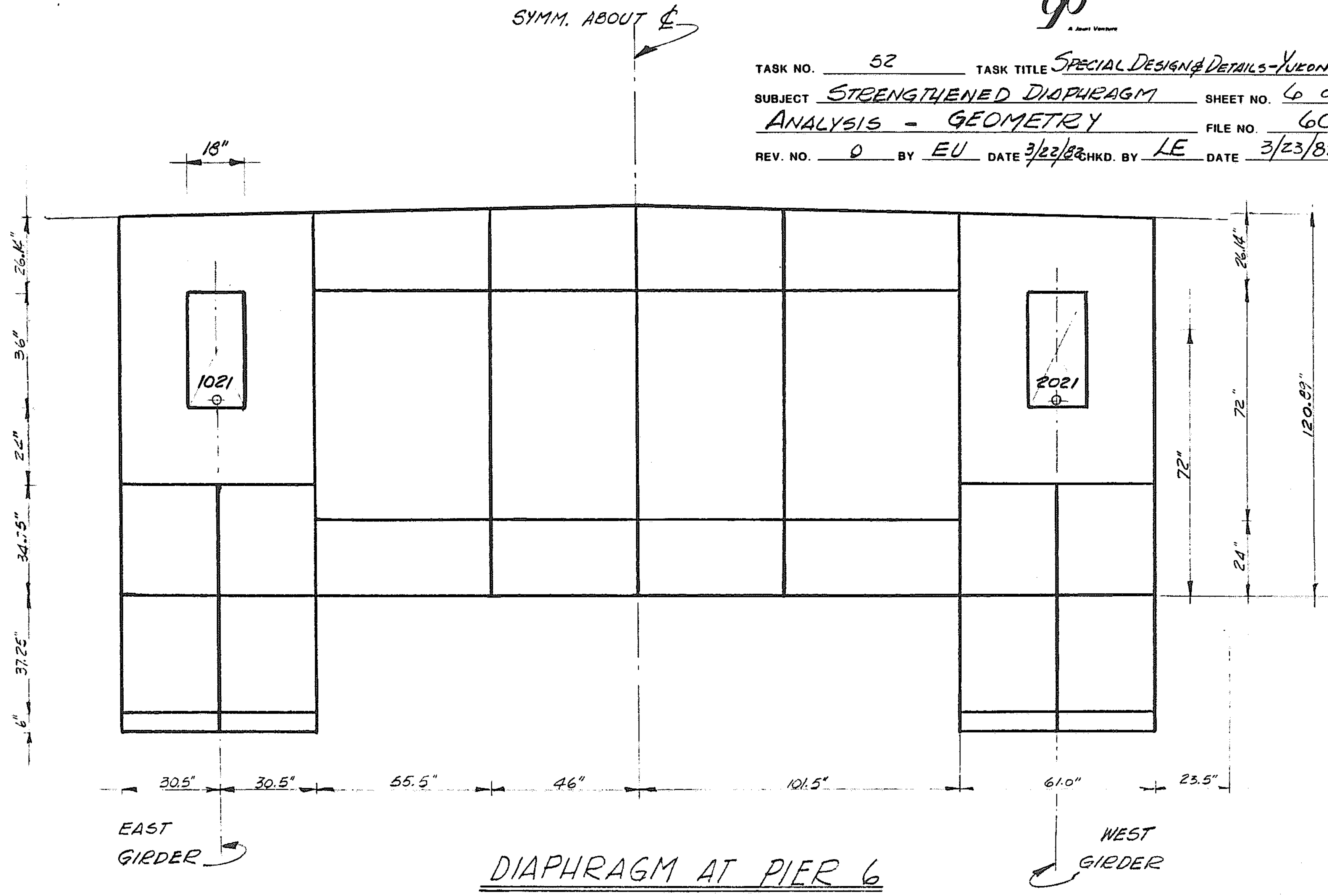
FOR CN1A REFER TO "CONTINGENCY FRACTURE ANALYSIS OF YUKON RIVER BRIDGE", REPORT

CN1A MODEL CONSIST OF : EXISTING YUKON RIVER BRIDGE + EXISTING OIL LINE IN OPERATING CONDITIONS

CN1ADPH1 MODEL CONSIST OF : CN1A + (FULL LANE LOAD + IMPACT) PLACED ON THE MOST CRITICAL LOCATION ON THE EAST BOUND. WITH THE DIAPHRAGM AT PIER 6 DISCRETELY MODELED AS SHOWN NEXT.

GULF INTERSTATE ENGINEERING COMPANY — MICHAEL BAKER, JR., INC.
A Joint Venture

TASK NO. 52 TASK TITLE Special Design & Details - Yukon River Bridge
SUBJECT Strengthened Diaphragm Analysis - Geometry SHEET NO. 6 of 60
FILE NO. 601
REV. NO. 0 BY EU DATE 3/22/82 CHKD. BY LE DATE 3/23/82



DIAPHRAGM AT PIER 6

CNIADPHI-MODEL

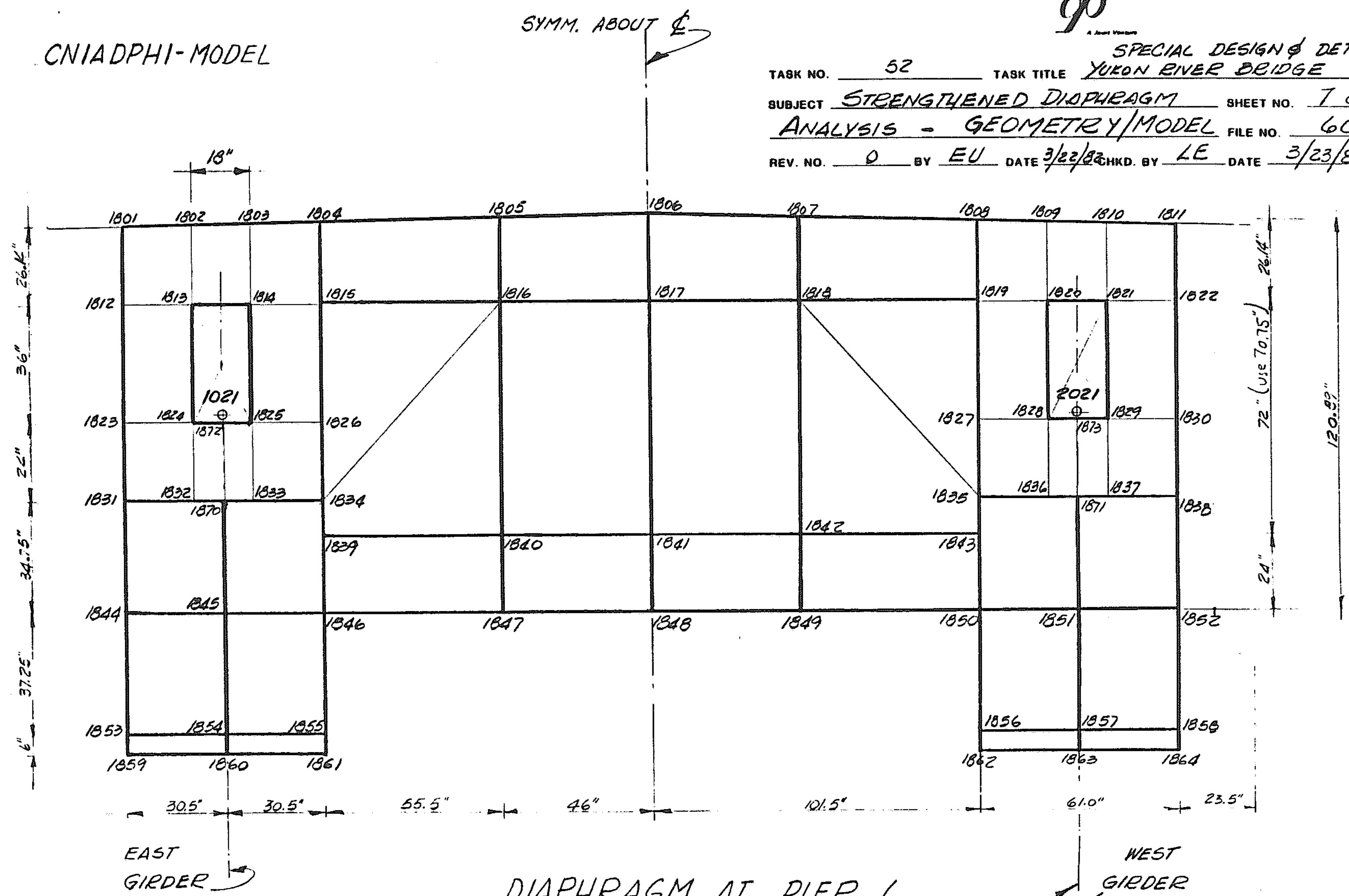
GULF INTERSTATE ENGINEERING COMPANY — MICHAEL BAKER, JR., INC.

A Joint Venture

TASK NO. 52 TASK TITLE SPECIAL DESIGN & DETAILS YUKON RIVER BRIDGE

SUBJECT STRENGTHENED DIAPHRAGM ANALYSIS - GEOMETRY/MODEL SHEET NO. 7 OF 60 FILE NO. 601

REV. NO. 0 BY EU DATE 3/22/82 CHKD. BY LE DATE 3/23/82



DIAPHRAGM AT PIER 6

LANE LOAD DISTRIBUTION FACTOR :

REFER TO "STUDY OF PIPE PLACEMENT ON WEST PIPEWAY OF THE YUKON RIVER BRIDGE" PAGES S-8 THRU S-25

D.F. = 0.70 (LANE LOAD) DISTRIBUTION FOR ONE TRUCK (p. S-21)

UNIFORM LOAD = 640 LBS/LF + { 18000 LBS FOR MOMENT; 26000 FOR SHEAR }

AASHTO-77 1.2.5 (D)

IMPACT :

$$I = \frac{50}{L+125}$$

$$I_{410} = \frac{50}{410+125} = 0.0935 \Rightarrow 9.4\%$$

$$I_{320} = \frac{50}{320+125} = 0.1124 \Rightarrow 11.3\%$$

USE $I = 10\%$

LIVE LOAD

EAST GIRDER LOAD :

$W = [1.10(0.640)] \times 0.70 = 0.4928 \text{ K/LF} \Rightarrow 0.0411 \text{ K/L.IN.}$

WEST GIRDER LOAD :

$W = [1.10(0.640)] \times 0.30 = 0.2112 \text{ K/LF} \Rightarrow 0.0176 \text{ K/L.IN.}$

TASK NO. 52 TASK TITLE Special Design & Details - Yukon River Bridge

SUBJECT Strengthened Diaphragm Analysis SHEET NO. 10 OF 60

Ansys Input Data FILE NO. 601

REV. NO. 0 BY L.E. DATE 3/22/82 CHKD. BY EU DATE 3/22/82

I. Node Co-ordinates ✓ (F-CARD 1)

Node	Co-ordinate		
	X	Y	Z
1801	23520.0	1495.58	162.5
2			141.0
3			123.0
4			101.5
5			46.0
6			0.0
7			-46.0
8			- 101.5
9			- 123.0
10			- 141.0
11		1495.58	- 162.5
12		1469.44	162.5
13			141.0
14			123.0
15			101.5
16			46.0
17			0.0
18			- 46.0
19			- 101.5
20			- 123.0
21			- 141.0
22	23520.0	1469.44	- 162.5

TASK NO. 52 TASK TITLE Special Design & Details - Yukon River Bridge

SUBJECT Strengthened Diaphragm Analysis SHEET NO. 11 of 60

Ansys Input Data FILE NO. 601

REV. NO. 0 BY L.E. DATE 3/22/82 CHKD. BY EU DATE 3/22/82

Node	Co-ordinate		
	X	Y	Z
1823	23520.0	1433.44	162.5
24			141.0
25			123.0
26			101.5
27			-101.5
28			-123.0
29			-141.0
30		1433.44	-162.5
1831		1409.44	162.5
32			141.0
33			123.0
34			101.5
35			-101.5
36			-123.0
37			-141.0
38		1409.44	-162.5
1839		1398.69	101.5
40			46.0
41			0.0
42			-46.0
43	23520.0	1398.69	-101.5

TASK NO. 52 TASK TITLE Special Design & Details – Yukon River Bridge

SUBJECT Strengthened Diaphragm Analysis SHEET NO. 12 of 60

ANSYS Input Data FILE NO. 601

REV. NO. 0 BY L.E. DATE 3/22/82 CHKD. BY EU DATE 3/22/82

Node	Co-ordinate		
	X	Y	Z
1844	23520.0	1374.69	162.5
45			132.0
46			101.5
47			46.0
48			0.0
49			- 46.0
50			- 101.5
51			- 132.0
52		1374.69	- 162.5
1853		1337.44	162.5
54			132.0
55			101.5
56			-101.5
57			- 132.0
58		1337.44	- 162.5
1859		1331.44	162.5
60			132.0
61			101.5
62			- 101.5
63			- 132.0
64	23520.0	1331.44	- 162.5

TASK NO. 52 TASK TITLE Special Design & Details - Yukon River Bridge

SUBJECT Strengthened Diaphragm Analysis
ANSYS Input Data

FILE NO. 601

REV. NO. 0 BY L.E. DATE 3/22/82 CHKD. BY EU DATE 3/22/82

Node	Co-ordinate		
	X	Y	Z
(K) 1865	23520.0	1300.0	-180.0
1870	23520.0	1409.44	132.0
1871	23520.0	1409.44	-132.0
1872	23520.0	1433.44	132.0
1873	23520.0	1433.44	-132.0

VII. Element Properties (D2 - Cards)

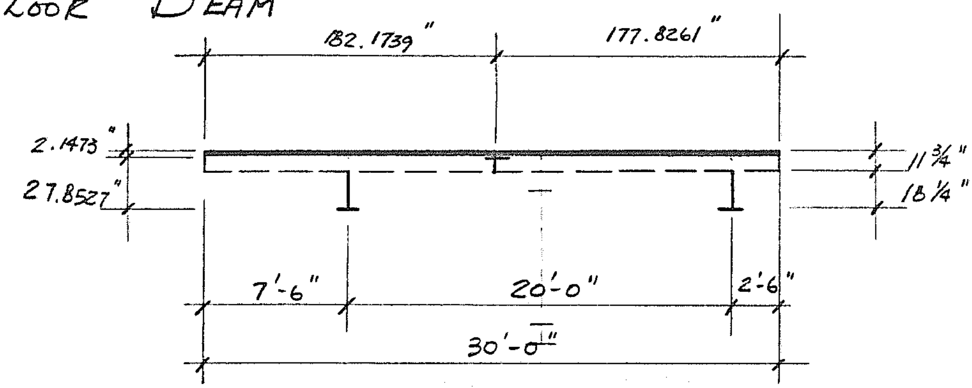
A. Beams - Stiff. 44

	Beam	Area	IZ1	IY1	TKZB1	TKYB1
33	1/2 x 6	3.0	9.0	0.0625	0.25	3.0
34	5/8 x 9	5.625	37.9688	0.1831	0.3125	4.5
35	3/4 x 12	9.0	108.0	0.4290	0.375	6.0
36	3/4 x 10	7.5	62.5	0.3516	0.375	5.0
37	Floor Beam	291.0937	2.099 E6	1.2421 E4	27.8527	182.1739

B. Plates - Stiff 63

	Plate	TK(I)
38	1/2	0.5
39	1 1/4	1.25

Floor Beam



Portion	Area	Y	AY	AY²	I_{oz}
Deck	270.0	119.625	32,298.75	3,863,737.97	12.6563
FB Web	11.0937	99.375	1,102.44	109,554.62	291.2687
FB Flange	10.0	90.5	905.0	81,902.50	0.2038
Totals	291.0937		34,306.19	4,055,195.09	304.1288

$$Y = \frac{34,306.19}{291.0937} = 117.8527 \text{ IN.}$$

$$I_{YY} = 304.1288 + 4,055,195.09 - (117.8527)^2(291.0937) = 12,420.74 \text{ IN}^4$$

PORTION	AREA	Z	AZ	AZ^2	I_{OY}
DECK	270.0	180.0	48,600.00	8,749,000.00	1,687,500.00
BEAM #1	10.5469	30.0	316.407	9,492.21	41.7118
BEAM #2	10.5469	270.0	2,847.663	768,869.01	41.7118
TOTAL	291.0938		51,764.07	9,527,361.21	1,687,583.42

$$Z = \frac{51,764.07}{291.0938} = 177.8261 \text{ IN}$$

$$I_{ZZ} = 1,687,583.42 + 9,527,361.21 - (177.8261)^2(291.0938 = 2,009,939.71 \text{ IN}^4$$

✓ III. H - CARDS

EX, 28,, 30.E3
ALPX, 28,, 6.5E-6
NUXY, 28,, 0.3
DENS, 28,, 7.324E-7

✓ IV. D - CARDS

5, 4,,, ,,, 1,, 1
6, 44
7, 63,,, 1, 1

✓ V. E - CARDS

A. BEAM ELEMENTS

1801, 1802, 1865,,,,,,28, 6, 37
1802, 1803, 1865,,,,,,28, 6, 37
1803, 1804, 1865,,,,,,28, 6, 37
1804, 1805, 1865,,,,,,28, 6, 37
1805, 1806, 1865,,,,,,28, 6, 37
1806, 1807, 1865,,,,,,28, 6, 37

GULF INTERSTATE ENGINEERING COMPANY — A Joint Venture — MICHAEL BAKER, JR., INC.

TASK NO. 52 TASK TITLE SPECIAL DESIGN & DETAILS – YUKON RIVER BRIDGE

SUBJECT STRENGTHENED DIAPHRAGM ANALYSIS SHEET NO. 18 OF 60

ANSYS INPUT DATA FILE NO. 601

REV. NO. 0 BY LE DATE 3/22/82 CHKD. BY EU DATE 3/22/82

1807, 1808, 1865, , , , , , , 28, 6, 37
1808, 1809,
1809, 1810,
1810, 1811, , 37
1813, 1814, 33
1815, 1816,
1816, 1817,
1817, 1818,
1818, 1819,
1820, 1821,
1824, 1825,
1828, 1829, , 33
(1) → 1831, 1832, , 34
1833, 1834,
1835, 1836,
(2) → 1837, 1838, , 34
1839, 1840, , 33
1840, 1841,
1841, 1842,
1842, 1843, , 33
1844, 1845, , 35
1845, 1846,
1846, 1847,
1847, 1848,
1848, 1849,
32 1849, 1850, 1865, , , , , , , 28, 6, 35

Form–JVE–2
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GULF INTERSTATE ENGINEERING COMPANY — MICHAEL BAKER, JR., INC.

A Joint Venture

TASK NO. 52 TASK TITLE SPECIAL DESIGN & DETAILS-YUKON RIVER BRIDGE

SUBJECT STRENGTHENED DIAPHRAGM ANALYSIS SHEET NO. 19 OF 60

ANSYS INPUT DATA FILE NO. 601

REV. NO. 0 BY LE DATE 3/22/82 CHKD. BY EU DATE 3/22/82

(1) { 1832, 1870, 1865, , , , , , 28, 6, 34
1870, 1833

(2) { 1836, 1871
36 1871, 1837

GULF INTERSTATE ENGINEERING COMPANY — MICHAEL BAKER, JR., INC.

A Joint Venture

TASK NO. 52 TASK TITLE Special Design & Details - Yukon River Bridge

SUBJECT Strenthened Diaphragm Analysis SHEET NO. 20 of 60

ANSYS Input Data FILE NO. 601

REV. NO. 0 BY LE DATE 3/22/82 CHKD. BY EU DATE 3/22/82

1850, 1851, 1865, , , , , , , 28, 6, 35
1851, 1852, , 35
1853, 1854, , 36
1854, 1855,
1856, 1857,
1857, 1858, , 36
1824, 1813, , 33
1825, 1814,
1828, 1820,
1829, 1821, , 33
1847, 1840,
1840, 1816,
1816, 1805,
1848, 1841,
1841, 1817,
1817, 1806,
1849, 1842,
1842, 1818,
1818, 1807, , 33
1860, 1854, , 34
1854, 1845,
1845, 1870,
1863, 1857,
1857, 1851,
W 1851, 1871, 1865, , , , , , , 28, 6, 34

Form-JVE-2

FM-91-A-002

TASK NO. 52 TASK TITLE Special Design & Details - Yukon River Bridge

SUBJECT Strengthened Diaphragm Analysis SHEET NO. 21 of 60

ANSYS Input Data FILE NO. 601

REV. NO. 0 BY LE DATE 3/22/82 CHKD. BY EU DATE 3/22/82

B. Plate Elements

1802, 1801, 1812, 1813, , , , , 28, 7, 39
1803, 1802, 1813, 1814,
1804, 1803, 1814, 1815, , 39
– 1805, 1804, 1815, 1816, , 38
1806, 1805, 1816, 1817,
1807, 1806, 1817, 1818,
– 1808, 1807, 1818, 1819, , 38
1809, 1808, 1819, 1820, , 39
1810, 1809, 1820, 1821,
1811, 1810, 1821, 1822, , 39
1824, 1813, 1812, 1823, ,
1814, 1825, 1826, 1815,
1831, 1832, 1824, 1823,
(5) 1832, 1870, 1872, 1824,
1833, 1834, 1826, 1825, , 39
(3) 1839, 1840, 1816, 1834, , 38
1840, 1841, 1817, 1816,
1841, 1842, 1818, 1817,
(4) 1842, 1843, 1835, 1818, , 38
1828, 1820, 1819, 1827, , 39
1821, 1829, 1830, 1822,
1835, 1836, 1828, 1827,
(6) 1836, 1871, 1873, 1828,
1837, 1838, 1830, 1829, , , , , 28, 7, 39
(3) 1816, 1815, 1834, 1834, , , , , 28, 7, 38
(4) 1819, 1818, 1835, 1835, , , , , 28, 7, 38

GULF INTERSTATE ENGINEERING COMPANY — MICHAEL BAKER, JR., INC.

A Joint Venture

TASK NO. 52 TASK TITLE SPECIAL DESIGN & DETAILS - YUKON RIVER BRIDGE

SUBJECT STRENGTHENED DIAPHRAGM ANALYSIS SHEET NO. 22 OF 60

ANSYS INPUT DATA FILE NO. 601

REV. NO. 0 BY LE DATE 3/22/82 CHKD. BY EU DATE 3/22/82

⑤ 1870, 1833, 1825, 1872, , , , , 28, 7, 39

⑥ 1871, 1837, 1829, 1873, , , , , 28, 7, 39

TASK NO. 52 TASK TITLE Special Design & Details - Yukon River Bridge

SUBJECT Strengthened Diaphragm Analysis SHEET NO. 23 of 60

ANSYS Input Data FILE NO. 601

REV. NO. 0 BY LE DATE 3/22/82 CHKD. BY EU DATE 3/22/82

1844, 1845, 1870, 1831, , , , , 28, 7, 39
1845, 1846, 1834, 1870, , 39
1846, 1847, 1840, 1839, , 38
1847, 1848, 1841, 1840,
1848, 1849, 1842, 1841,
1849, 1850, 1843, 1842, , 38
1850, 1851, 1871, 1835, , 39
1851, 1852, 1838, 1871,
1853, 1854, 1845, 1844,
1854, 1855, 1846, 1845,
1856, 1857, 1851, 1850,
1857, 1858, 1852, 1851,
1859, 1860, 1854, 1853,
1860, 1861, 1855, 1854,
1862, 1863, 1857, 1856,
44 1863, 1864, 1858, 1857, , , , , 28, 7, 39

✓ X. Coupled Nodes (J - Card)

UX,,, 10, 1021, 1801, 1804, 1815, 1839, 1846, 1861, 1860, 1859, 1844
UY
UZ
ROTX
ROTY
ROTZ

UX,,, 10, 2021, 1808, 1811, 1852, 1864, 1863, 1862, 1850, 1843, 1819
UY
UZ
ROTX
ROTY
ROTZ

✓ XI. REMOVE FLOOR BEAM (1021 – 2021) FROM BOTH MODELS.

✓ XII. WAVE FRONT

INSERT THE FOLLOWING CARD BEFORE THE WAVE FRONT WHICH BEGINS AT NODES 1021 & 2021

1801, -1

WAVE FRONT

~~7,-1~~
22,1000,2000,-1
27,1021,2021,602,603,-1
~~32,1033,1036,-1~~
35,1042,2042,-1
36,1045,2045,-1
~~37,1051,2051,502,503,-1~~
39,1054,2054,-1
40,1063,2063,-1
~~43,1066,2066,-1~~
45,1072,2072,-1
47,1078,2078,-1
~~48,1081,2081,403,404,-1~~
51,1090,2090,-1
53,1096,2096,-1
~~55,1102,2102,-1~~
56,1099,2099,-1
57,1111,2111,303,304,-1
~~59,1114,2114,-1~~
60,1117,2117,-1
63,1126,2126,-1
~~64,1129,2129,-1~~
67,1141,2141,204,205,-1
68,1141,2141,-1
~~74,-1~~
/NOPR
END

✓ XIII. Live Load (P-Cards)

107, 2, 0.0411, 200

201, 2, 0.0176, 294

-1

TASK NO. 52 TASK TITLE SPECIAL DESIGN & DETAILS - YUKON RIVER BRIDGE
SUBJECT STRENGTHENED DIAPHRAGM SHEET NO. 21 OF 60
ANALYSIS - COMPUTER OUTPUT RESULTS FILE NO. 601
REV. NO. 0 BY EU DATE 3/22/82 CHKD. BY LE DATE 3/23/82

RESULTS:

IN GENERAL THE STRESSES THROGHOUT THE DIAPHRAGM ARE LOW. THE MAXIMUM STRESS IS RECORDED AT ELEMENT 686 (SEE STRESSES @ PIER 6) = 6.69 KSI

THE ALLOWABLE STRESS IS:

$$t_w = \frac{D[f_b]^{1/2}}{23000} \qquad \text{AASHTO 1.7.43 (C)}$$

D = DEPTH OF WEB (IN)
t_w = THICKNESS OF WEB (IN)
f_b = CALCULATED COMPRESSIBE BENDING STRESS (PSI) IN FLANGE

THEN

$D = 72''$

$t = 1/2''$ (FURNISHED)

f_b → BEAM ELEMENT 1815-1816 = 1.75 KSI

$$t_w \text{ REQUIRED} = \frac{72[1750]^{1/2}}{23000} = 0.13 \text{ IN}$$

t_w FURNISHED > t_w REQUIRED O.K. ✓

GULF INTERSTATE ENGINEERING COMPANY — MICHAEL BAKER, JR., INC. — A Joint Venture

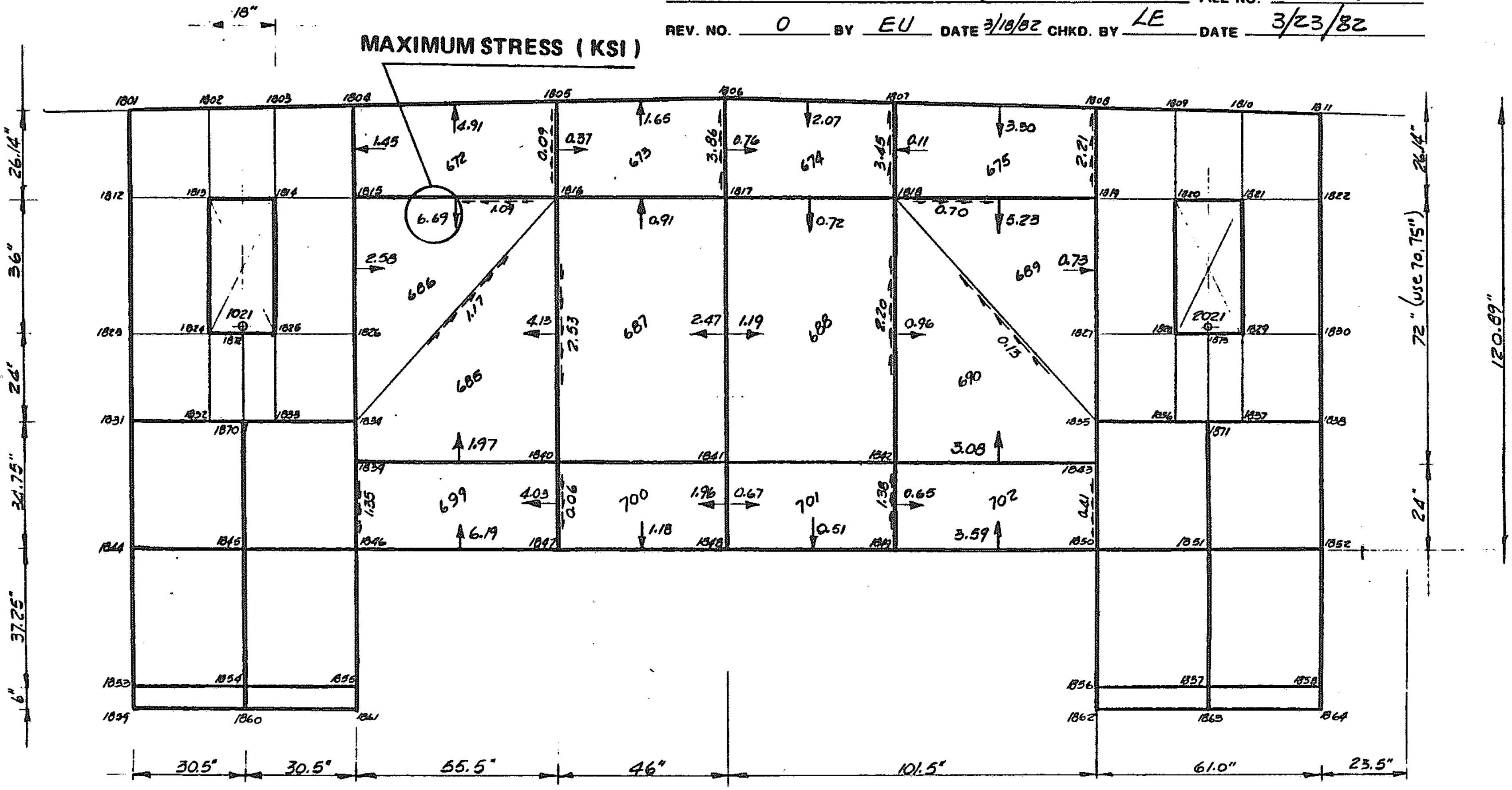
TASK NO. 52 TASK TITLE SPECIAL DESIGN & DETAILS YUKON RIVER BRIDGE

SUBJECT STRENGTHENED DIAPHRAGM ANALYSIS - STRESSES @ PIER 6 SHEET NO. 28 OF 60

FILE NO. 601

REV. NO. 0 BY EU DATE 3/18/82 CHKD. BY LE DATE 3/23/82

CN1ADPH1-MODEL



CN3A1DPH

COMPUTER MODEL

COMPUTER MODEL TO DETERMINE THE STRESSES IN THE DIAPHRAGM AT PIER 6 : CN3A1DPH

MODEL CN3A1DPH IS MODIFIED FROM CN3A1

FOR CN3A1 REFER TO "STUDY OF ALTERNATIVE PIPE PLACEMENT ON YUKON RIVER BRIDGE" REPORT

CN3A1 MODEL CONSIST OF : EXISTING YUKON RIVER BRIDGE
+ EXISTING OIL LINE
+ CENTER GAS LINE
IN OPERATING CONDITION

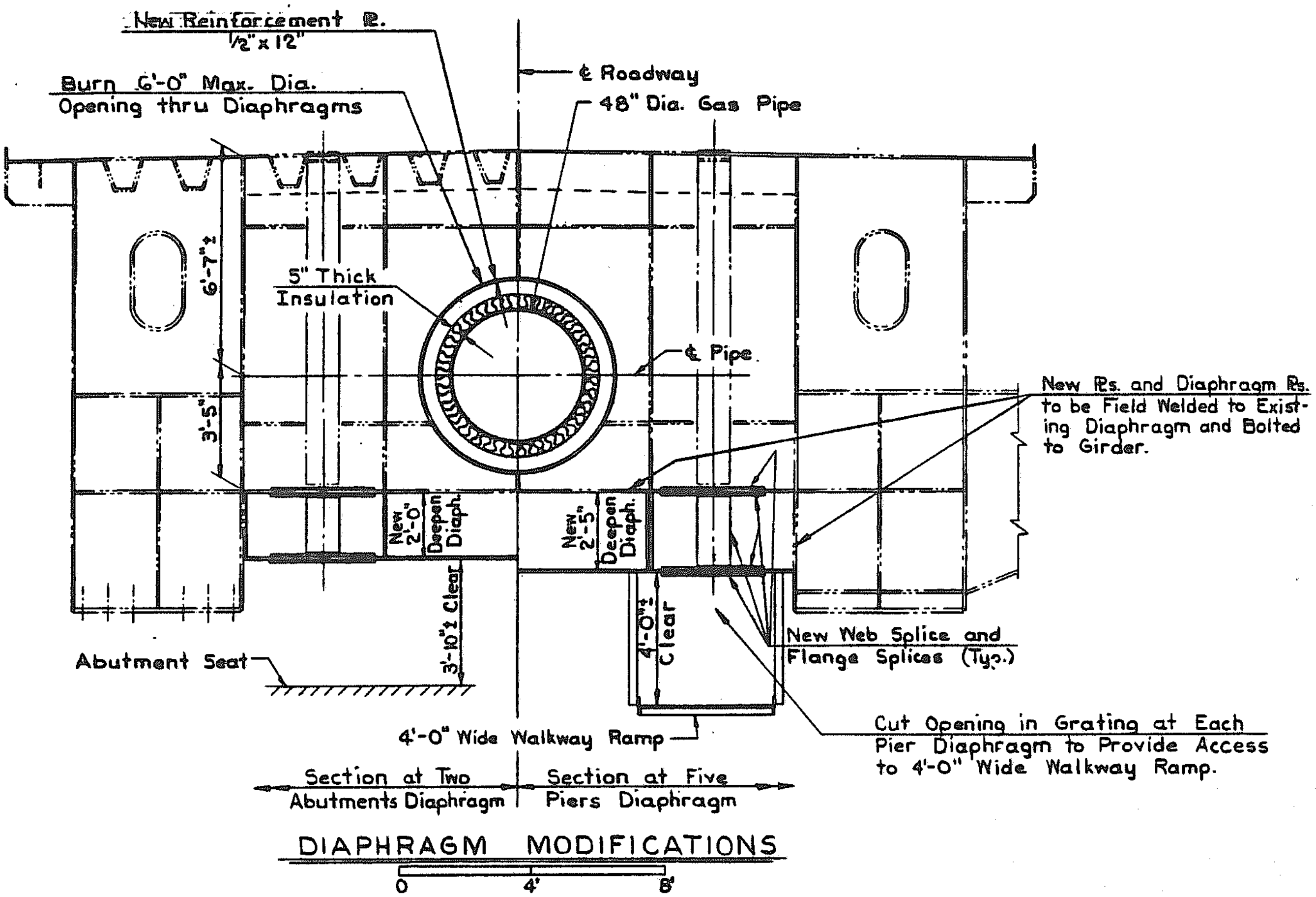
CN3A1DPH MODEL CONSIST OF : CN3A1 + (FULL LANE LOAD + IMPACT) PLACED ON THE MOST CRITICAL LOCATION ON THE EAST BOUND. WITH THE DIAPHRAGM AT PIER 6 AS SHOWN ON THE NEXT PAGE. DIAPHRAGM AT PIER 6 COMPUTER MODEL WAS DISCRETELY MODELED AS SHOWN ON THE FOLLOWING PAGES.

TASK NO. 52 TASK TITLE Special Design & Details - Yukon River Bridge

SUBJECT Strengthened Diaphragm Analysis SHEET NO. 31 of 60

Analysis - Preliminary Details FILE NO. 602

REV. NO. 0 BY LE DATE 3/22/82 CHKD. BY EU DATE 3/22/82



DIAPHRAGM MODIFICATIONS

Note:

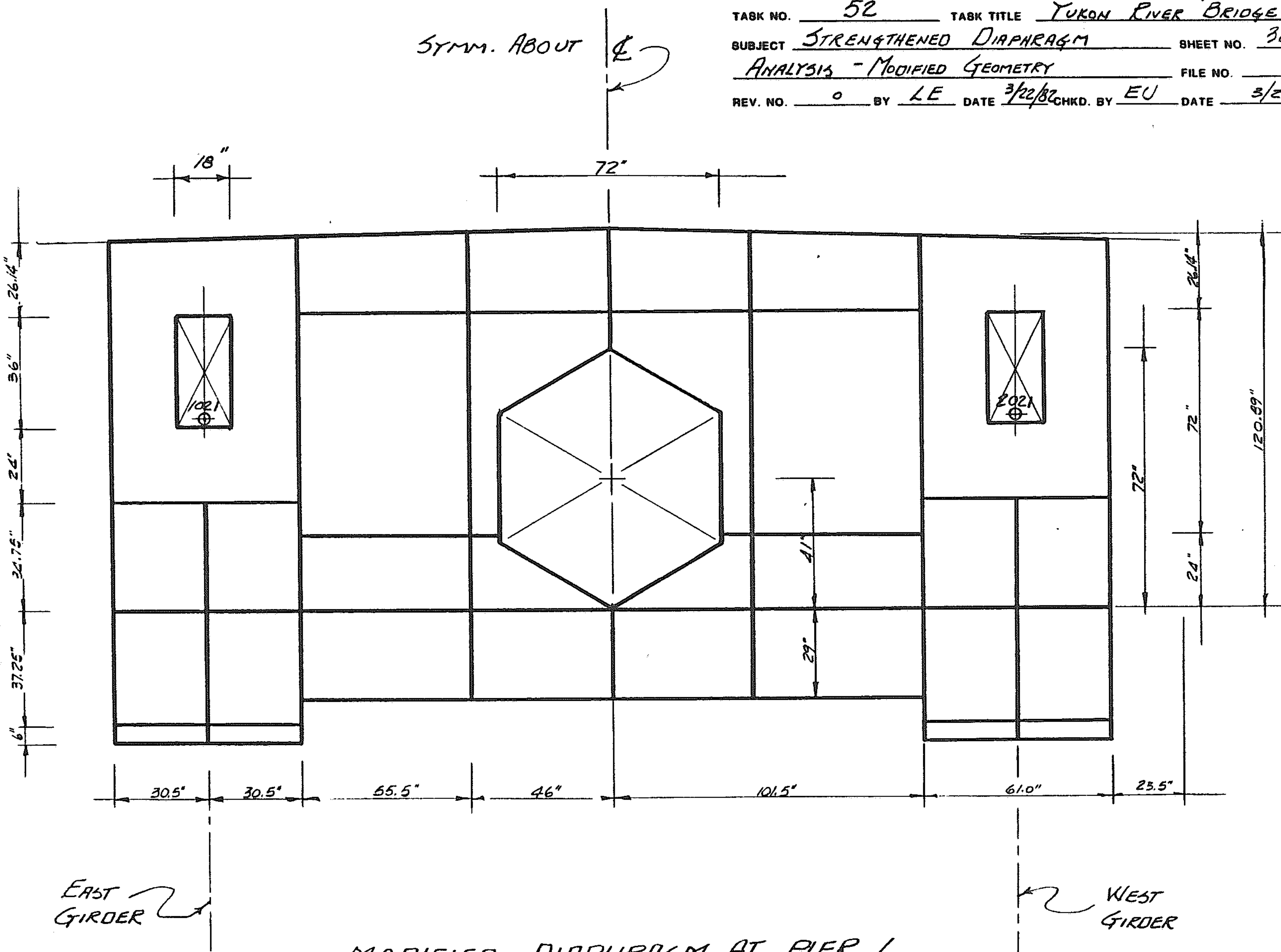
These details are reproduced from the report "Study of Alternative Pipe Placement on Yukon River Bridge - Revision No. 1", December, 1981, Drawing Number 4680-13-11-W-SK-064J Rev. A

INSTALLATION OF GAS LINE SUPPORTS ON BRIDGE

1. Establish One Way Traffic on the Bridge to Facilitate Construction.
2. Reinforce Diaphragms at the Abutments and over the Piers.
3. Install New Gas Line Support Beams and Walkway Support Beams between the Box Girders using High Strength Bolts for the Connections. Remove the Existing Catwalks and Install the New Maintenance Grating.
4. Cut Openings thru the Diaphragm Webs and Reinforce the Edges of the Plates.

GULF INTERSTATE ENGINEERING COMPANY — MICHAEL BAKER, JR., INC.

TASK NO. 52	TASK TITLE Special Design & Details Yukon River Bridge		
SUBJECT Strengthened Diaphragm Analysis - Modified Geometry		SHEET NO. 32 of 60	FILE NO. 602
REV. NO. 0	BY LE DATE 3/22/82	CHKD. BY EU	DATE 3/22/82



MODIFIED DIAPHRAGM AT PIER 6

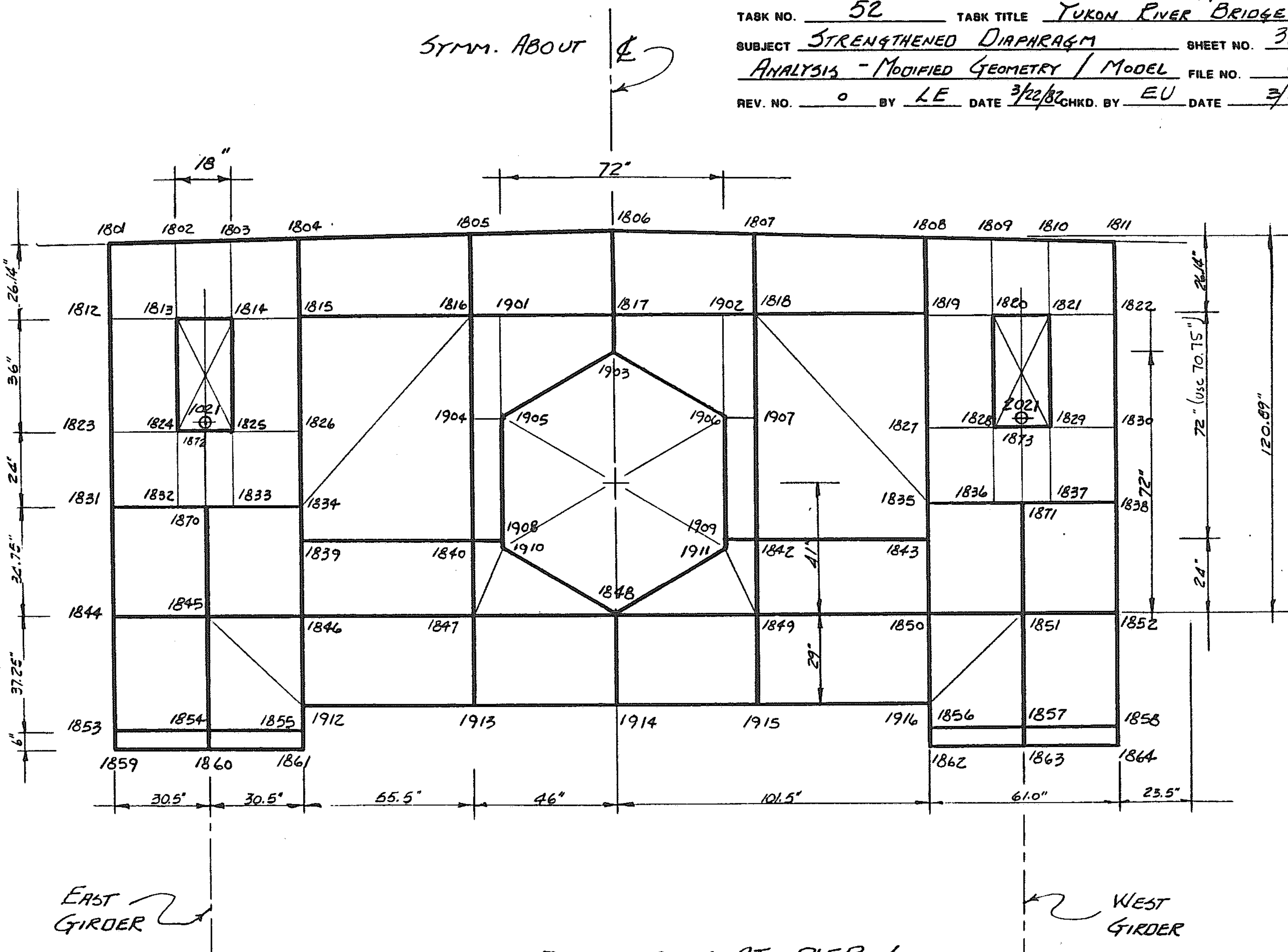
GULF INTERSTATE ENGINEERING COMPANY — MICHAEL BAKER, JR., INC.

TASK NO. 52 TASK TITLE SPECIAL DESIGN & DETAILS YUKON RIVER BRIDGE

SUBJECT STRENGTHENED DIAPHRAGM ANALYSIS - MODIFIED GEOMETRY / MODEL SHEET NO. 33 OF 60

FILE NO. 602

REV. NO. 0 BY LE DATE 3/22/82 CHKD. BY EU DATE 3/22/82



MODIFIED DIAPHRAGM AT PIER 6

TASK NO. 52 TASK TITLE Special Design & Details - Yukon River Bridge
SUBJECT Strengthened Diaphragm Analysis SHEET NO. 34 of 60
ANSYS Input Data FILE NO. 602
REV. NO. 0 BY LE DATE 3/22/82 CHKD. BY EU DATE 3/22/82

I. Node Co-ordinates (F - CARD2)

Node	Co-ordinate X	Co-ordinate Y	Co-ordinate Z
1801	23520.0	1495.58	162.5
2	↑	↑	141.0
3			123.0
4			101.5
5			46.0
6			0.0
7			-46.0
8			-101.5
9			-123.0
10		↓	-141.0
11		1495.58	-162.5
12		1469.44	162.5
13		↑	141.0
14			123.0
15			101.5
16			46.0
17			0.0
18			-46.0
19			-101.5
20			-123.0
21	↓	↓	-141.0
22	23520.0	1469.44	-162.5

TASK NO. 52 TASK TITLE Special Design & Details – Yukon River Bridge

SUBJECT Strengthened Diaphragm Analysis SHEET NO. 35 of 60

ANSYS Input Data FILE NO. 602

REV. NO. 0 BY LE DATE 3/22/82 CHKD. BY EU DATE 3/22/82

Node	Co-ordinate		
	X	Y	Z
1823	23520.0	1433.44	162.5
24	↑	↑	141.0
25			123.0
26			101.5
27			-101.5
28			-123.0
29		↓	-141.0
30		1433.44	-162.5
1831		1409.44	162.5
32		↑	141.0
33			123.0
34			101.5
35			-101.5
36			-123.0
37		↓	-141.0
38		1409.44	-162.5
1839		1398.69	101.5
40		↑	46.0
41			0.0
42			-46.0
43	↓ 23520.0	↓ 1398.69	-101.5

TASK NO. 52 TASK TITLE Special Design & Details - Yukon River Bridge

SUBJECT Strengthened Diaphragm Analysis SHEET NO. 36 of 60

ANSYS Input Data FILE NO. 602

REV. NO. 0 BY LE DATE 3/22/82 CHKD. BY EU DATE 3/22/82

Node	Co-ordinate		
	X	Y	Z
1844	23520.0	1374.69	162.5
45			132.0
46			101.5
47			46.0
48			0.0
49			- 46.0
50			- 101.5
51			- 132.0
52		1374.69	- 162.5
1853		1337.44	162.5
54			132.0
55			101.5
56			-101.5
57			- 132.0
58		1337.44	- 162.5
1859		1331.44	162.5
60			132.0
61			101.5
62			- 101.5
63			- 132.0
64	23520.0	1331.44	- 162.5

TASK NO. 52 TASK TITLE Special Design & Details - Yukon River Bridge

SUBJECT Strengthened Diaphragm Analysis SHEET NO. 37 of 60

ANSYS Input Data FILE NO. 602

REV. NO. 0 BY LE DATE 3/22/82 CHKD. BY EU DATE 3/22/82

Node	Co-ordinate		
	X	Y	Z
(K) 1865	23520.0	1300.0	−180.0
1870	23520.0	1409.44	132.0
1871	23520.0	1409.44	−132.0
1872	23520.0	1433.44	132.0
1873	23520.0	1433.44	−132.0
1901	23520.0	1469.44	41.0
1902		1469.44	−41.0
1903		1457.83	0.0
1904		1437.04	46.0
1905		1437.04	41.0
1906		1437.04	−41.0
1907		1437.04	−46.0
1908		1398.69	41.0
1909		1398.69	−41.0
1910		1395.47	41.0
1911		1395.47	−41.0
1912		1345.69	101.5
1913			46.0
1914			0.0
1915			−46.0
1916	23520.0	1345.69	−101.5

II. Element Properties (D2 -Cards)

A. Beams - Stiff. 44

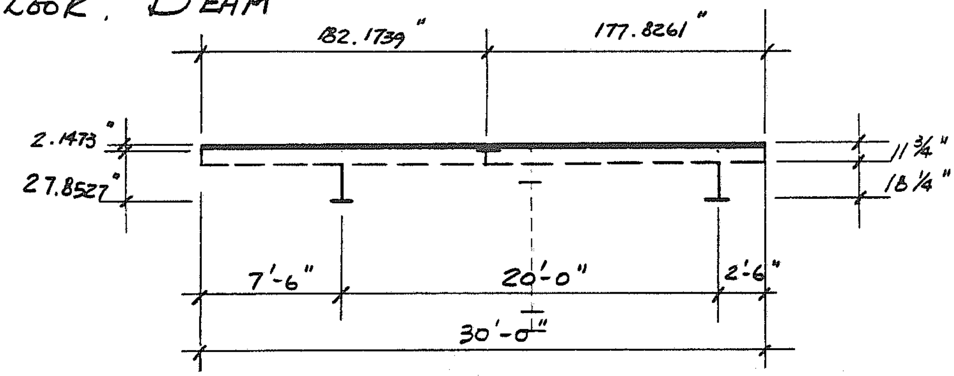
	Beam	Area	I_{Z1}	I_{Y1}	TKZB1	TKYB1
33	½ x 6	3.0	9.0	0.0625	0.25	3.0
34	⅝ x 9	5.625	37.9688	0.1831	0.3125	4.5
35	¾ x 12	9.0	108.0	0.4290	0.375	6.0
36	¾ x 10	7.5	62.5	0.3516	0.375	5.0
37	Floor Beam	291.0937	2.099 E6	1.2421 E4	27.8527	182.1739
40	½" x 12	6.0	72.0	0.125	0.25	6.0

B. Plates - Stiff 63

	Plate	TK(I)
38	½	0.5
39	1¼	1.25

TASK NO. 52 TASK TITLE Special Design & Details - Yukon River Bridge
SUBJECT Strengthened Diaphragm Analysis SHEET NO. 39 of 60
ANSYS Input Data FILE NO. 602
REV. NO. 0 BY L.E. DATE 3/22/82 CHKD. BY EU DATE 3/22/82

Floor Beam



Portion	Area	Y	AY	AY²	I_{oz}
Deck	270.0	119.625	32,298.75	3,863,737.97	12.6563
FB Web	11.0937	99.375	1,102.44	109,554.62	291.2687
FB Flange	10.0	90.5	905.0	81,902.50	0.2038
Totals	291.0937		34,306.19	4,055,195.09	304.1288

$$Y = \frac{34,306.19}{291.0937} = 117.8527 \text{ in.}$$

$$I_{YY} = 304.1288 + 4,055,195.09 - (117.8527)^2 (291.0937) = 12,420.74 \text{ in}^4$$

TASK NO. 52 TASK TITLE SPECIAL DESIGN & DETAILS - YUKON RIVER BRIDGE

SUBJECT STRENGTHENED DIAPHRAGM ANALYSIS SHEET NO. 40 OF 60

ANSYS INPUT DATA FILE NO. 602

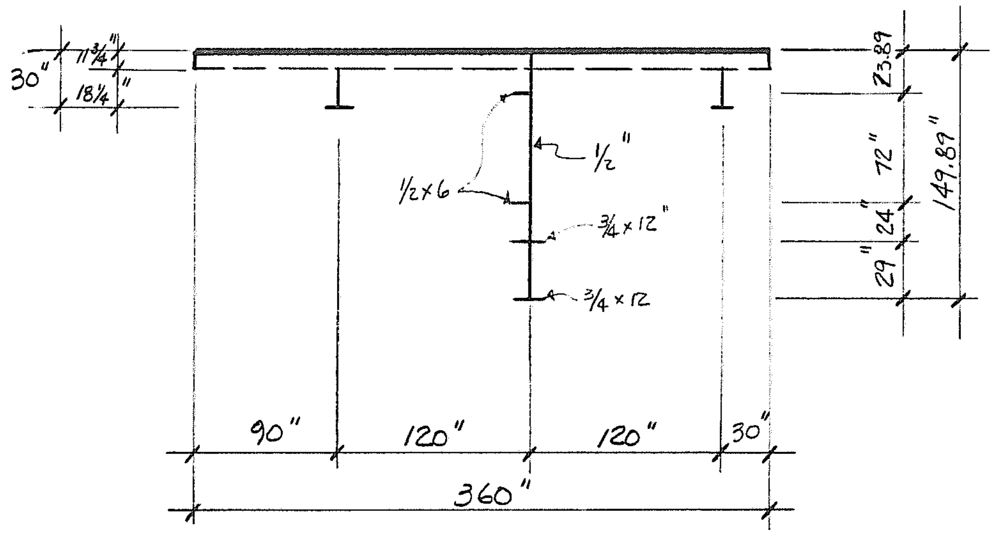
REV. NO. 0 BY L.E. DATE 3/22/82 CHKD. BY EU DATE 3/22/82

PORTION	AREA	Z	AZ	AZ²	I_{OY}
DECK	270.0	180.0	48,600.00	8,749,000.00	1,687,500.00
BEAM #1	10.5469	30.0	316.407	9,492.21	41.7118
BEAM #2	10.5469	270.0	2,847.663	768,869.01	41.7118
TOTAL	291.0938		51,764.07	9,527,361.21	1,687,583.42

$$Z = \frac{51,764.07}{291.0938} = 177.8261 \text{ IN}$$

$$I_{ZZ} = 1,687,583.42 + 9,527,361.21 - (177.8261)^2(291.0938 = 2,009,939.71 \text{ IN}^4$$

MODIFIED DIAPHRAGM : (AT THE DIAPHRAGM ENDS)



PORTION	AREA	Y	AY	AY²	I₀
EXISTING DIAPH.	371.3437	132.9053	49,353.5459	6,559,347.817	387,744.56
MD WEB	14.5	14.5	210.25	3,048.625	1,016.21
MD FLANGE	9.0	0.375	3.375	1.266	5.06
TOTAL	394.8431		49,567.1709	6,562,397.708	388,765.83

$$\bar{Y} = \frac{49{,}567.1709}{394.8437} = 125.54 \text{ IN.}$$

$$I_{YY} = 388{,}765.83 + 6{,}562{,}397.708 - (125.54)^2(394.8437) = 728{,}690.12 \text{ IN}^4$$

$$S_{TOP} = \quad = 29{,}920.98 \text{ IN}^3$$

$$S_{BOTTOM} = \quad = 5{,}804.62 \text{ IN}^3$$

GULF INTERSTATE ENGINEERING COMPANY — A Joint Venture — MICHAEL BAKER, JR., INC.

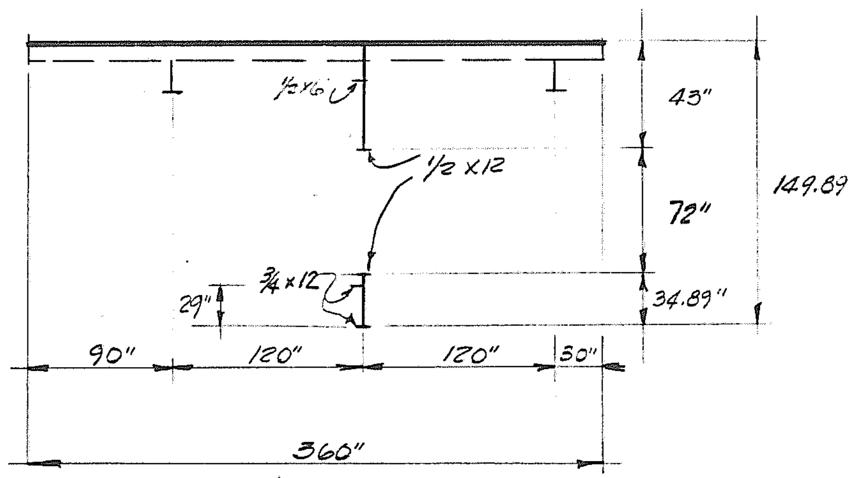
TASK NO. 52 TASK TITLE SPECIAL DESIGN & DETAILS - YUKON RIVER BRIDGE

SUBJECT STRENGTHENED DIAPHRAGM ANALYSIS SHEET NO. 42 OF 60

MOMENT OF INERTIA OF MODIFIED DIAPHRAGM FILE NO. 602

REV. NO. 0 BY EU DATE 3/23/82 CHKD. BY LE DATE 3/23/82

MODIFIED DIAPHRAGM : (AT CENTER OF DIAPHRAGM)



PORTION	AREA	Y	A·Y	$A \cdot Y^2$	I_o
DECK	270.00	148.625	40128.75	5,964,135.47	12.6563
FB WEB	11.0937	128.375	1424.15	182,825.74	291.2687
FB FLANGE	10.00	119.500	1195.00	142,802.50	0.2038
DIAPH. WEB 1	21.5	128.390	2760.385	354,405.83	3312.7917
DIAPH WEB 2	17.445	17.445	304.328	5,309.00	1769.6675
DIAPH STIFF. 1	3.00	125.890	377.67	47,544.88	0.0625
2	6.00	106.890	641.34	68,552.83	0.1250
3	6.00	34.890	209.34	7,303.87	0.1250
4	9.00	29.00	261.00	7,569.00	0.4219
5	9.00	0.375	3.38	1.27	0.4219
TOTAL	363.0387		47,305.3430	6,780,450.39	5387.74

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$$Y = \frac{47,305.34}{363.04} = 130.30 \text{ IN.}$$

$$I_{YY} = 5387.74 + 6,780,450.39 - 363.04\,(130.30)^2 = 621,769.47 \text{ IN}^4$$

$$S_{TOP} = \frac{621,769.47 \text{ IN}^4}{19.59 \text{ IN}} = 31739.13 \text{ IN}^3$$

$$S_{BOTTOM} = \frac{621,769.47 \text{ IN}^4}{130.30 \text{ IN}} = 4771.83 \text{ IN}^3$$

SECTION PROPERTIES OF EXISTING DIAPHRAGM
REFER TO "CONTENGENCY FRACTURE ANALYSIS OF YUKON RIVER BRIDGE" REPORT P. P16.

$Y =$

$I_{YY} = 387,744 \text{ IN}^4$

$S_{TOP} = 24,091 \text{ IN}^3$

$S_{BOTTOM} = 3,732 \text{ IN}^3$

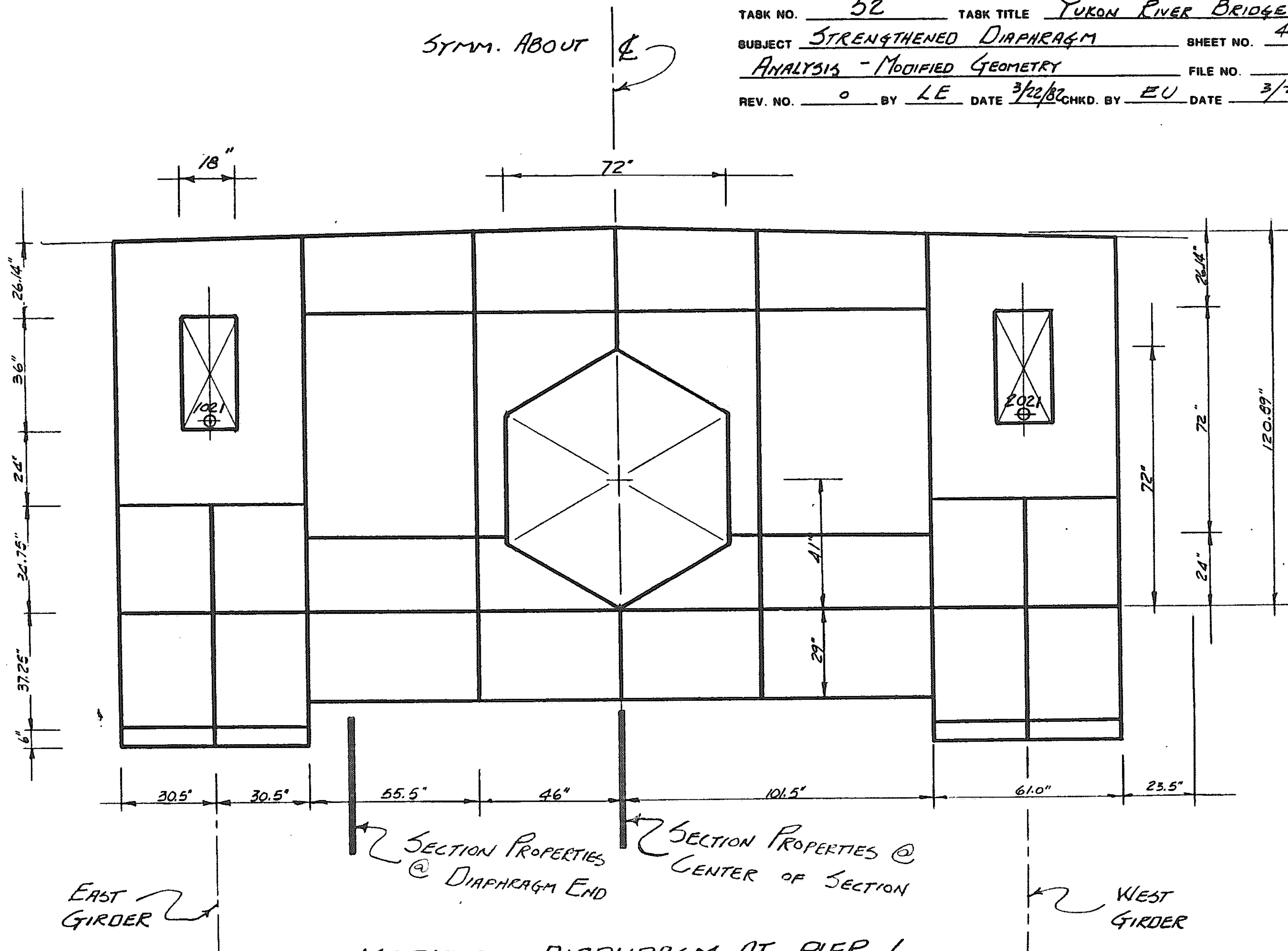
THEREFORE IT IS CONSERVATIVE TO USE THE EXISTING DIAPHRAGM MOMENT OF INERTIA IN THE CN3A1DPH MODEL.

GULF INTERSTATE ENGINEERING COMPANY — MICHAEL BAKER, JR., INC.

TASK NO. 52 TASK TITLE SPECIAL DESIGN & DETAILS YUKON RIVER BRIDGE

SUBJECT STRENGTHENED DIAPHRAGM ANALYSIS - MODIFIED GEOMETRY SHEET NO. 44 OF 60 FILE NO. 602

REV. NO. 0 BY LE DATE 3/22/82 CHKD. BY EU DATE 3/22/82



MODIFIED DIAPHRAGM AT PIER 6

GULF INTERSTATE ENGINEERING COMPANY — MICHAEL BAKER, JR., INC.

A Joint Venture

TASK NO. 52 TASK TITLE Special Design & Details - Yukon River Bridge

SUBJECT Strengthened Diaphragm Analysis SHEET NO. 45 OF 60

ANSYS Input Data FILE NO. 602

REV. NO. 0 BY LE DATE 3/22/82 CHKD. BY EU DATE 3/22/82

III. H - Cards

EX, 28 ,, 30.E3
ALPX, 28 ,, 6.5 E-6
NUXY, 28 ,, 0.3
DENS, 28 ,, 7.324 E-7

IV. D - Cards

5, 4,,, ,,, 1 ,, 1
6 , 44
7, 63, , ,1,1

V. E - Cards

A. Beam Elements

1801 , 1802 , 1865, , , , , ,28, 6, 37
1802, 1803 , 1865, , , , , ,28, 6 , 37
1803, 1804 , 1865 , , , , , ,28, 6, 37
1804, 1805, 1865, , , , , ,28, 6, 37
1805, 1806 , 1865, , , , , ,28, 6, 37
1806, 1807 , 1865, , , , , ,28, 6, 37

GULF INTERSTATE ENGINEERING COMPANY — MICHAEL BAKER, JR., INC.

A Joint Venture

TASK NO. 52 TASK TITLE Special Design & Details – Yukon River Bridge

SUBJECT Strengthened Diaphragm Analysis SHEET NO. 46 of 60

ANSYS Input Data FILE NO. 602

REV. NO. 0 BY LE DATE 3/22/82 CHKD. BY EU DATE 3/22/82

1807, 1808, 1865, , , , , , 28, 6, 37
1808, 1809,
1809, 1810,
1810, 1811, , 37
1813, 1814, 33
1815, 1816,
1816, 1817,
1817, 1818,
1818, 1819,
1820, 1821,
1824, 1825,
1828, 1829, , 33
(1) → 1831, 1832, , 34
1833, 1834,
1835, 1836,
(2) → 1837, 1838, , 34
1839, 1840, , 33
1840, ~~1841~~ 1908,
~~1841~~ 1909, 1842,
1842, 1843, , 33
1844, 1845, , 35
1845, 1846,
1846, 1847,
1847, 1848,
1848, 1849,
1849, 1850, 1865, , , , , , 28, 6, 35

Form-JVE-2

FM-91-A-002

GULF INTERSTATE ENGINEERING COMPANY — MICHAEL BAKER, JR., INC.

A Joint Venture

TASK NO. 52 TASK TITLE SPECIAL DESIGN & DETAILS - YUKON RIVER BRIDGE

SUBJECT STRENGTHENED DIAPHRAGM ANALYSIS SHEET NO. 47 OF 60

ANSYS INPUT DATA FILE NO. 602

REV. NO. 0 BY LE DATE 3/22/82 CHKD. BY EU DATE 3/22/82

① { 1832, 1870, 1865, , , , , , 28, 6, 34
1870, 1833 }

② { 1836, 1871
36 1871, 1837 }

GULF INTERSTATE ENGINEERING COMPANY — MICHAEL BAKER, JR., INC.

A Joint Venture

TASK NO. 52 TASK TITLE Special Design & Details - Yukon River Bridge

SUBJECT Strengthened Diaphragm Analysis SHEET NO. 48 of 60

ANSYS Input Data FILE NO. 602

REV. NO. 0 BY LE DATE 3/22/82 CHKD. BY EU DATE 3/22/82

1850, 1851, 1865, , , , , ,28, 6, 35
1851, 1852, , 35
1853, 1854, , 36
1854, 1855,
1856, 1857,
1857, 1858, , 36
1824, 1813, , 33
1825, 1814,
1828, 1820,
1829, 1821, , 33
1847, 1840,
1840, 1816,
1816, 1805,
~~1848, 1841,~~
1903 ~~1841~~, 1817,
1817, 1806,
1849, 1842,
1842, 1818,
1818, 1807, , 33
1860, 1854, , 34
1854, 1845,
1845, 1870,
1863, 1857,
1857, 1851,
ω 1851, 1871, 1865, , , , , ,28, 6, 34

GULF INTERSTATE ENGINEERING COMPANY — MICHAEL BAKER, JR., INC.

A Joint Venture

TASK NO. 52 TASK TITLE Special Design & Details - Yukon River Bridge

SUBJECT Strengthened Diaphragm Analysis SHEET NO. 49 of 60

ANSYS Input Data FILE NO. 602

REV. NO. 0 BY LE DATE 3/22/82 CHKD. BY EU DATE 3/22/82

Beams (cont'd)

1905, 1903, 1865, , , , , , 28, 6, 40
1903, 1906,
1910, 1848,
1848, 1911,
1910, 1905,
1911, 1906, , 40
1912, 1913, , 35
1913, 1914,
1914, 1915,
1915, 1916, , 35
1913, 1843, , 33
1914, 1848,
1915, 1849, 1865, , , , , , 28, 6, 33

GULF INTERSTATE ENGINEERING COMPANY — MICHAEL BAKER, JR., INC.

A Joint Venture

TASK NO. 52 TASK TITLE Special Design & Details - Yukon River Bridge

SUBJECT Strengthened Diaphragm Analysis SHEET NO. 50 of 60

ANSYS Input Data FILE NO. 602

REV. NO. 0 BY LE DATE 3/22/82 CHKD. BY EU DATE 3/22/82

B. PLATE ELEMENTS

1802, 1801, 1812, 1813, , , , , 28, 7, 39

1803, 1802, 1813, 1814,

1804, 1803, 1814, 1815, , 39

1805, 1804, 1815, 1816, , 38

1806, 1805, 1816, 1817,

1807, 1806, 1817, 1818,

1808, 1807, 1818, 1819, , 38

1809, 1808, 1819, 1820, , 39

1810, 1809, 1820, 1821,

1811, 1810, 1821, 1822, , 39

1824, 1813, 1812, 1823, ,

1814, 1825, 1826, 1815,

1831, 1832, 1824, 1823,

(5) 1832, 1870, 1872, 1824,

1833, 1834, 1826, 1825, , 39

(3) 1839, 1840, 1816, 1834, , 38

~~1840, 1841, 1817, 1816,~~

~~1841, 1842, 1818, 1817,~~

(4) 1842, 1843, 1835, 1818, , 38

1828, 1820, 1819, 1827, , 39

1821, 1829, 1830, 1822,

1835, 1836, 1828, 1827,

(6) 1836, 1871, 1873, 1828,

1837, 1838, 1830, 1829, , , , , 28, 7, 39

(3) 1816, 1815, 1834, 1834, , , , , 28, 7, 38

(4) 1819, 1818, 1835, 1835, , , , , 28, 7, 38

TASK NO. 52	TASK TITLE Special Design & Details - Yukon River Bridge		
SUBJECT Strengthened Diaphragm Analysis		SHEET NO. 51 of 60	
ANSYS Input Data		FILE NO. 602	
REV. NO. 0	BY LE	DATE 3/22/82	CHKD. BY EU DATE 3/22/82

⑤ 1870, 1833, 1825, 1872, , , , , 28, 7, 39

22 ⑥ 1871, 1837, 1829, 1873, , , , , 28, 7, 39

GULF INTERSTATE ENGINEERING COMPANY — MICHAEL BAKER, JR., INC.

A Joint Venture

TASK NO. 52 TASK TITLE Special Design & Details - Yukon River Bridge

SUBJECT Strengthened Diaphragm Analysis SHEET NO. 52 of 60

ANSYS Input Data FILE NO. 602

REV. NO. 0 BY LE DATE 3/22/82 CHKD. BY EU DATE 3/22/82

1844, 1845, 1870, 1831, , , , , 28, 7, 39

1845, 1846, 1834, 1870, , 39

1846, 1847, 1840, 1839, , 38

~~1847, 1848, 1841, 1840,~~

~~1848, 1849, 1842, 1841,~~

1849, 1850, 1843, 1842, , 38

1850, 1851, 1871, 1835, , 39

1851, 1852, 1838, 1871,

1853, 1854, 1845, 1844,

~~1854, 1855, 1846, 1845,~~

~~1856, 1857, 1851, 1850,~~

1857, 1858, 1852, 1851,

1859, 1860, 1854, 1853,

1860, 1861, 1855, 1854,

1862, 1863, 1857, 1856,

1863, 1864, 1858, 1857, , , , , 28, 7, 39

Form-JVE-2

FM-91-A-002

GULF INTERSTATE ENGINEERING COMPANY — MICHAEL BAKER, JR., INC.

A Joint Venture

TASK NO. 52 TASK TITLE Special Design & Details - Yukon River Bridge

SUBJECT Strengthened Diaphragm Analysis SHEET NO. 53 of 60

ANSYS Input Data FILE NO. 602

REV. NO. 0 BY LE DATE 3/22/82 CHKD. BY EU DATE 3/22/82

1904 , 1905 , 1901 , 1816 , , , , , 28 , 7 , 38
1905 , 1903 , 1817 , 1901 ,
1903 , 1906 , 1902 , 1817 ,
1906 , 1907 , 1818 , 1902 ,
1908 , 1905 , 1904 , 1840 ,
1906 , 1909 , 1842 , 1907 ,
1910 , 1908 , 1840 , 1847 ,
1848 , 1910 , 1847 , 1847 ,
1911 , 1848 , 1849 , 1849 ,
1909 , 1911 , 1849 , 1842 ,
1847 , 1846 , 1912 , 1913 ,
1848 , 1847 , 1913 , 1914 ,
1849 , 1848 , 1914 , 1915 ,
1850 , 1849 , 1915 , 1916 , , 38
1846 , 1845 , 1912 , 1912 , , 39
1854 , 1855 , 1912 , 1845 ,
1851 , 1850 , 1916 , 1916 ,
1856 , 1857 , 1851 , 1916 , , , , , 28 , 7 , 39

X. Coupled Nodes (J - Card)

UX,,, 10, 1021, 1801, 1804, 1815, ~~1834~~ 1912, 1846, 1861, 1860, 1859, 1844
UY
UZ
ROTX
ROTY
ROTZ

UX,,, 10, 2021, 1808, 1811, 1852, 1864, 1863, 1862, 1850, ~~1832~~ 1916, 1819
UY
UZ
ROTX
ROTY
ROTZ

XI. Remove floor beam (1021 - 2021) from both models.

XII. Wave Front

Insert the following card before the wave front which begins at nodes 1021 & 2021

1801, -1

```
~~7,-1~~
22,1000,2000,-1
27,1021,2021,602,603,-1
~~32,1033,1036,-1~~
35,1042,2042,-1
36,1045,2045,-1
~~37,1051,2051,502,503,-1~~
39,1054,2054,-1
40,1063,2063,-1
~~43,1066,2066,-1~~
45,1072,2072,-1
47,1078,2078,-1
~~48,1081,2081,403,404,-1~~
51,1090,2090,-1
53,1096,2096,-1
~~55,1102,2102,-1~~
56,1099,2099,-1
57,1111,2111,303,304,-1
~~59,1114,2114,-1~~
60,1117,2117,-1
63,1126,2126,-1
~~64,1129,2129,-1~~
67,1141,2141,204,205,-1
68,1141,2141,-1
~~74,-1~~
/NOPR
END
```

Wave Front

XIII. Live Load (P-Cards)

107, 2, 0.0411, 200

201, 2, 0.0176, 294

-1

LANE LOAD DISTRIBUTION FACTOR :

REFER TO "STUDY OF PIPE PLACEMENT ON WEST PIPEWAY OF THE YUKON RIVER BRIDGE" PAGES S-8 THRU S-25

D.F. = 0.70 (LANE LOAD) DISTRIBUTION FOR ONE TRUCK (p. S-21)

UNIFORM LOAD = 640 LBS/LF + { 18000 LBS FOR MOMENT; 26000 FOR SHEAR }

AASHTO-77 1.2.5 (D)

IMPACT :

$$I = \frac{50}{L+125}$$

$$I_{410} = \frac{50}{410+125} = 0.0935 \approx 9.4\%$$

$$I_{320} = \frac{50}{320+125} = 0.1124 \approx 11.3\%$$

USE $I = 10\%$

LIVE LOAD

EAST GIRDER LOAD :

$W = [1.10(0.640)] \times 0.70 = 0.4928\ ^{K}/_{LF} \Rightarrow 0.0411\ ^{K}/_{L.IN.}$

WEST GIRDER LOAD :

$W = [1.10(0.640)] \times 0.30 = 0.2112\ ^{K}/_{LF} \Rightarrow 0.0176\ ^{K}/_{L.IN.}$

RESULTS:

IN GENERAL THE STRESSES THROUGHOUT THE DIAPHRAGM ARE LOW. THE MAXIMUM STRESS (SEE NEXT PAGE) OCCURS AT ELEMENT 717 WITH A VALUE OF 7.60 KSI.

THE ALLOWABLE STRESS IS:

$$t_w = \frac{D\,[f_b]^{1/2}}{23000} \qquad \text{AASHTO } 1.7.43\ (c)$$

D = DEPTH OF WEB (IN)

t_w = THICKNESS OF WEB (IN)

f_b = CALCULATED COMPRESSIBLE BENDING STRESS (PSI) IN FLANGE

THEN $D = 72''$

$t = \frac{1}{2}''$ (FURNISHED)

$f_b = 2.62^{ksi}$ BEAM ELEMENT 1815-1816

$$t_w \text{ REQUIRED} = \frac{72\,[2620]^{1/2}}{23000} = 0.16 \text{ IN}$$

t_w FURNISHED > t_w REQUIRED OK

GULF INTERSTATE ENGINEERING COMPANY — MICHAEL BAKER, JR., INC.

A Joint Venture

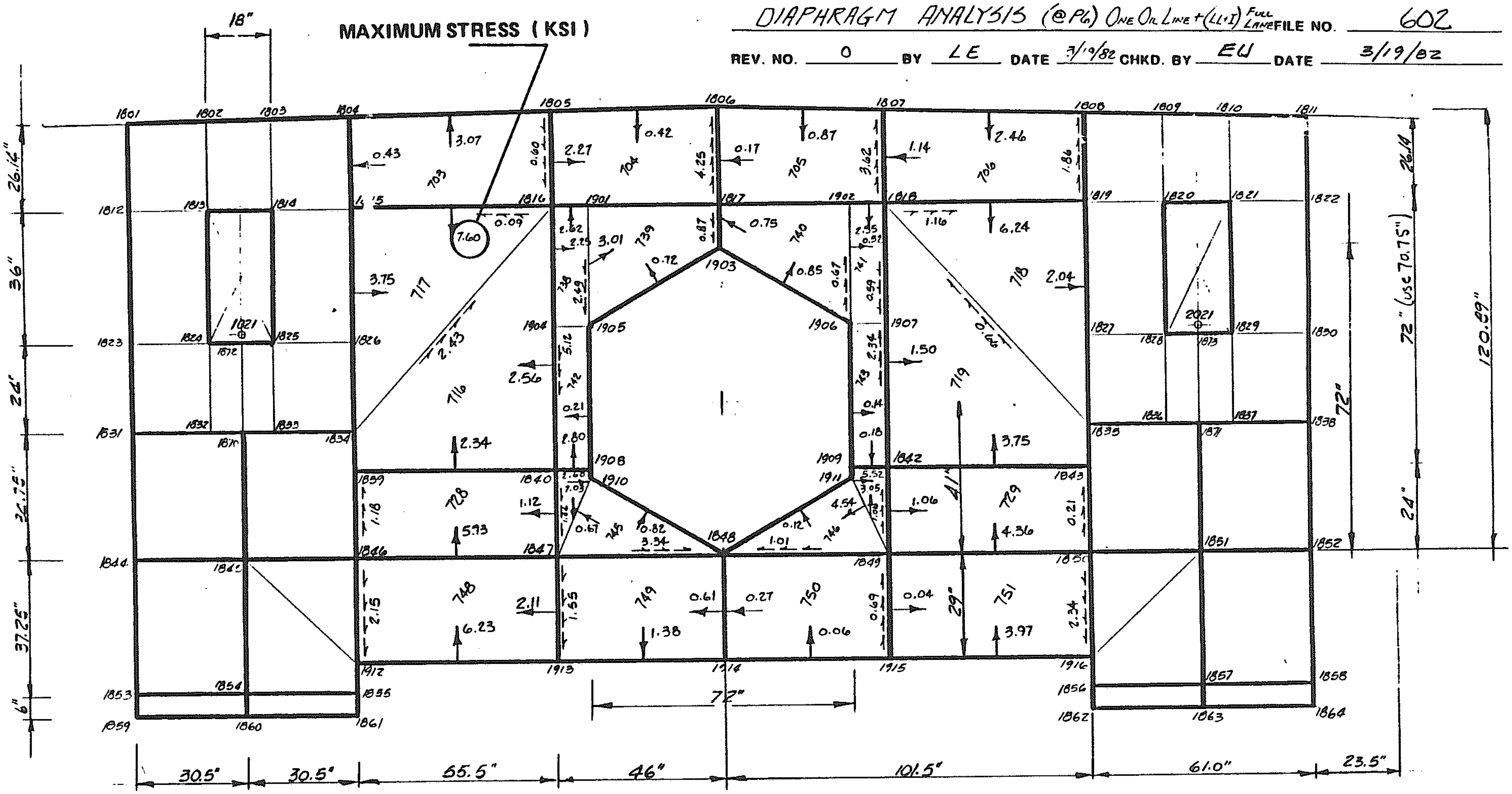
CN3A1DPH · Model

TASK NO. 52 **TASK TITLE**

SUBJECT Yukon River Bridge AS 64 MP 361.3 **SHEET NO.** 60 of 60

Diaphragm Analysis (@ P6) One Oil Line + (LL+I) Full Lane **FILE NO.** 602

REV. NO. 0 **BY** LE **DATE** 3/19/82 **CHKD. BY** EW **DATE** 3/19/82



APPENDIX D

RESULTS OF PSI COMPUTER STUDY OF BOLT HOLE CONFIGURATIONS

GULF INTERSTATE ENGINEERING COMPANY — MICHAEL BAKER, JR., INC.

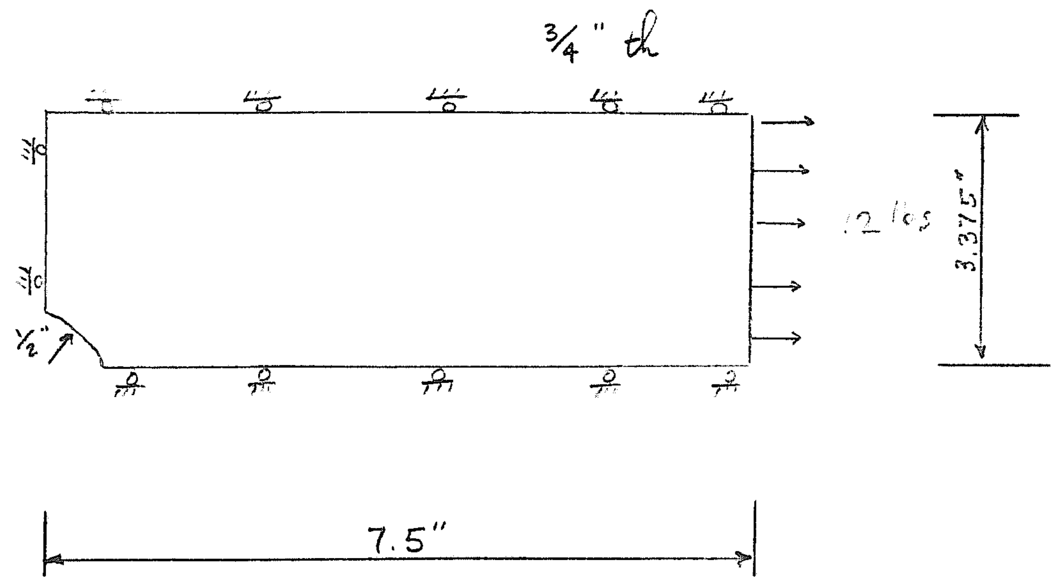
A Joint Venture

TASK NO. 52 TASK TITLE Special Pipeline Design - Yukon River Bridge

SUBJECT Technical Concerns SHEET NO. D1 of 13

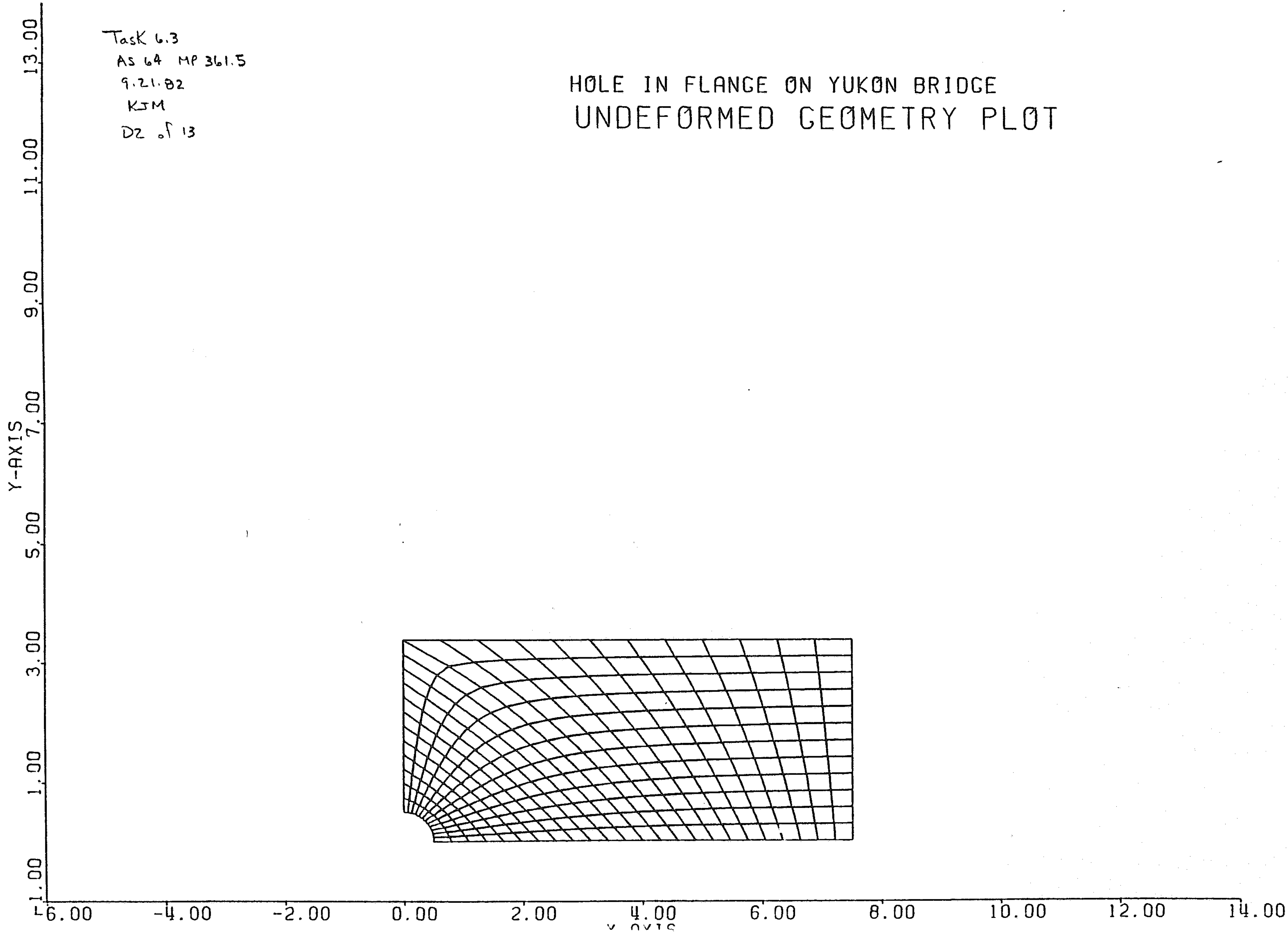
As 64 MP 361.5 FILE NO. 61.1

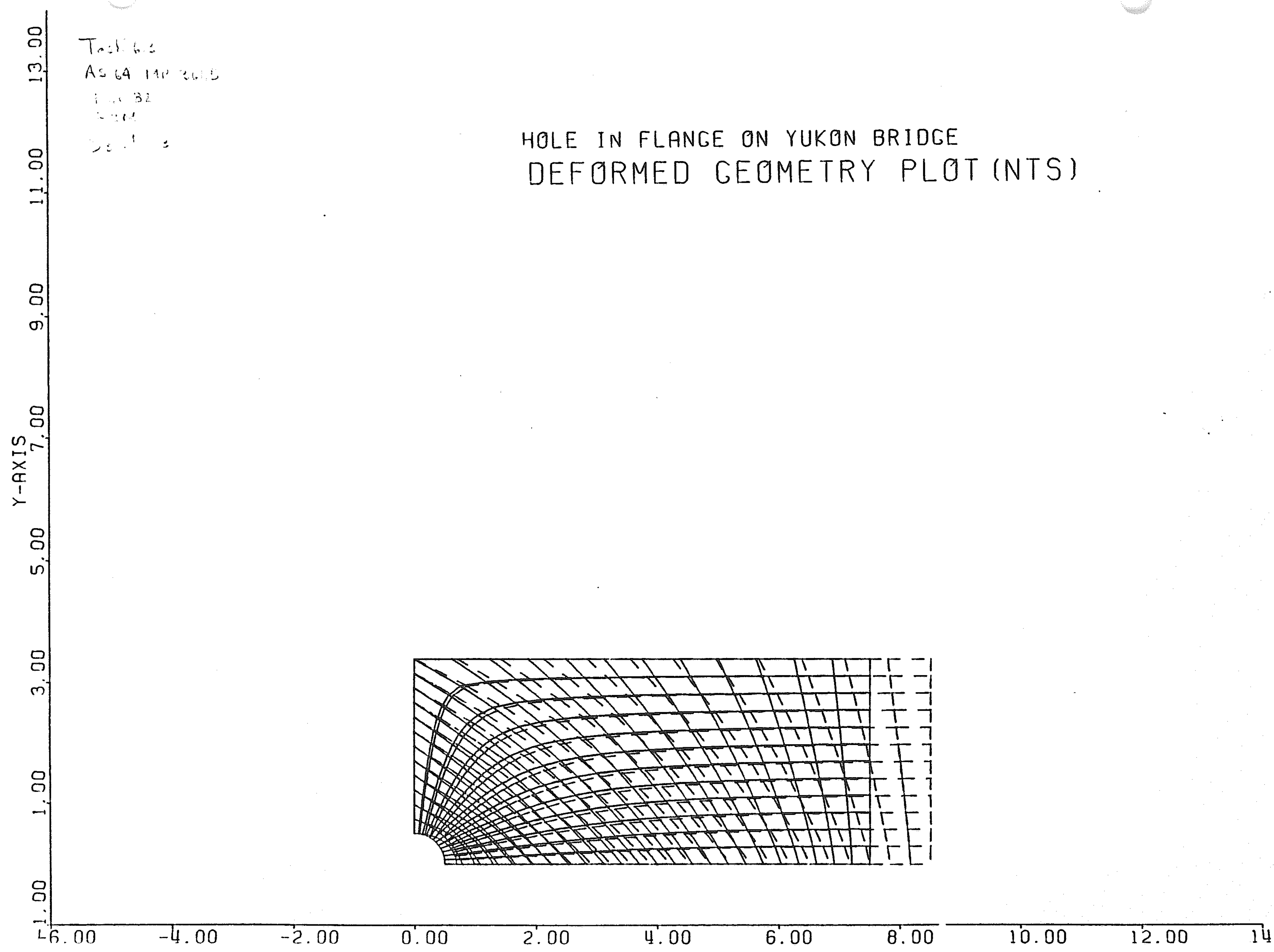
REV. NO. 0 BY KJM DATE 9-20-82 CHKD. BY KJM DATE 9-21-82



$$\sigma_{\text{gross section}} = 12 / (3.375 \times 0.75)$$

$$= 4.74 \text{ psi}$$


Task 6.3
AS 64 MP 361.5
9.21.82
KJM
D2 of 13
HOLE IN FLANGE ON YUKON BRIDGE
UNDEFORMED GEOMETRY PLOT
Y-AXIS
13.00
11.00
9.00
7.00
5.00
3.00
1.00
-1.00
-6.00
-4.00
-2.00
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
X-AXIS


HOLE IN FLANGE ON YUKON BRIDGE
DEFORMED GEOMETRY PLOT (NTS)
Y-AXIS
13.00
11.00
9.00
7.00
5.00
3.00
1.00
-1.00
-6.00
-4.00
-2.00
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.

HØLE IN FLANGE ØN YUKØN BRIDGE

SIGMAX STRESS CØNTØURS

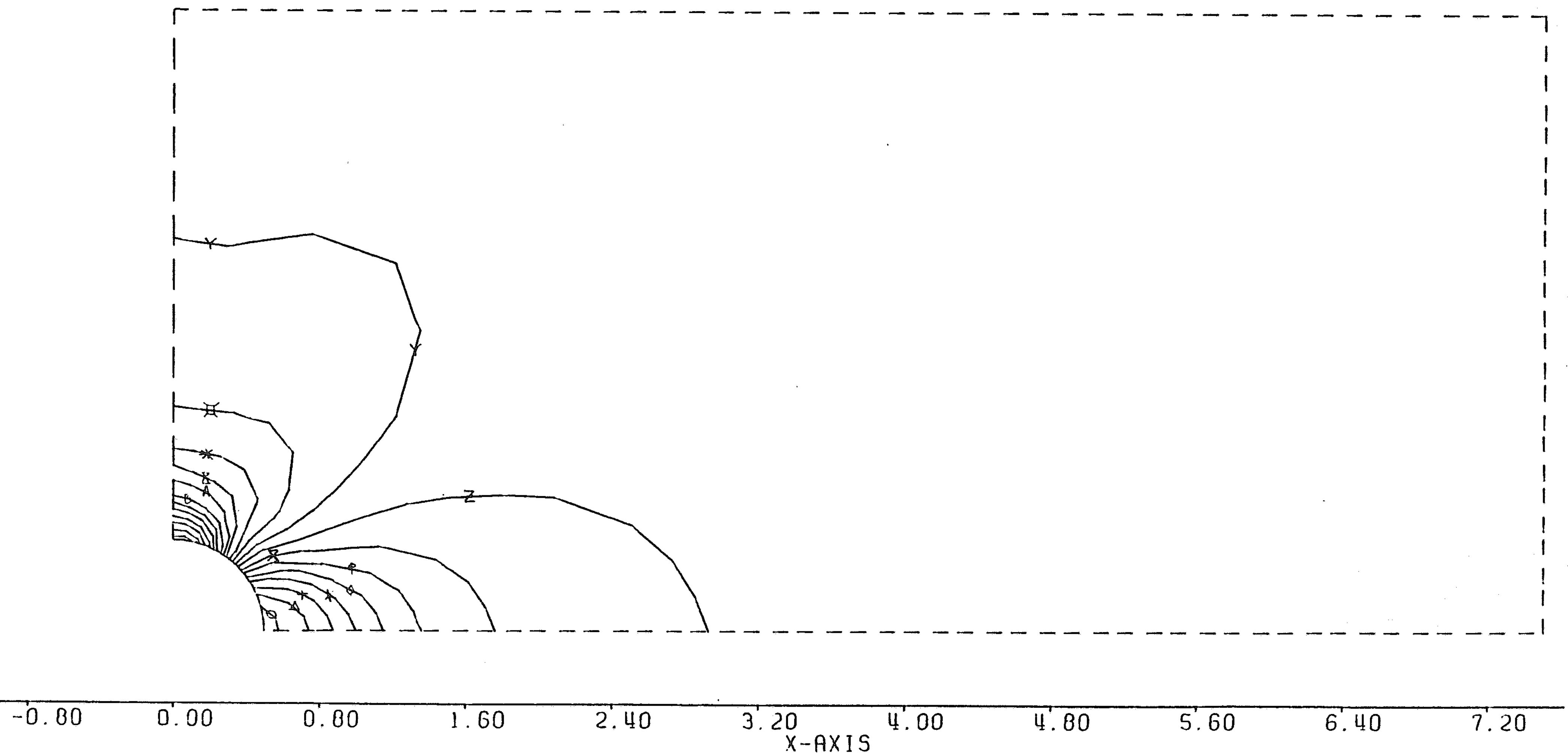
CØNTØURS REQUESTED

⦶	.10787E+01
△	.15711E+01
+	.20636E+01
×	.25560E+01
◇	.30484E+01
↑	.35409E+01
⧗	.40333E+01
Z	.45257E+01
Y	.50182E+01
⌧	.55106E+01
✳	.60030E+01
⧖	.64955E+01
A	.69879E+01
B	.74803E+01
C	.79728E+01
D	.84652E+01
E	.89576E+01
F	.94501E+01
G	.99425E+01
H	.10435E+02

Task 6.3
AS 64 MP 361.5
9.21.82
KJM
D4 [illegible] 13

Task 6.3
AC64 MP 361 5
9.21.82
KJM
35 of 3

HØLE IN FLANGE ØN YUKØN BRIDGE
SIGMAX STRESS CØNTØURS



HOLE IN FLANGE ON YUKON BRIDGE

SIGMAY STRESS CONTOURS

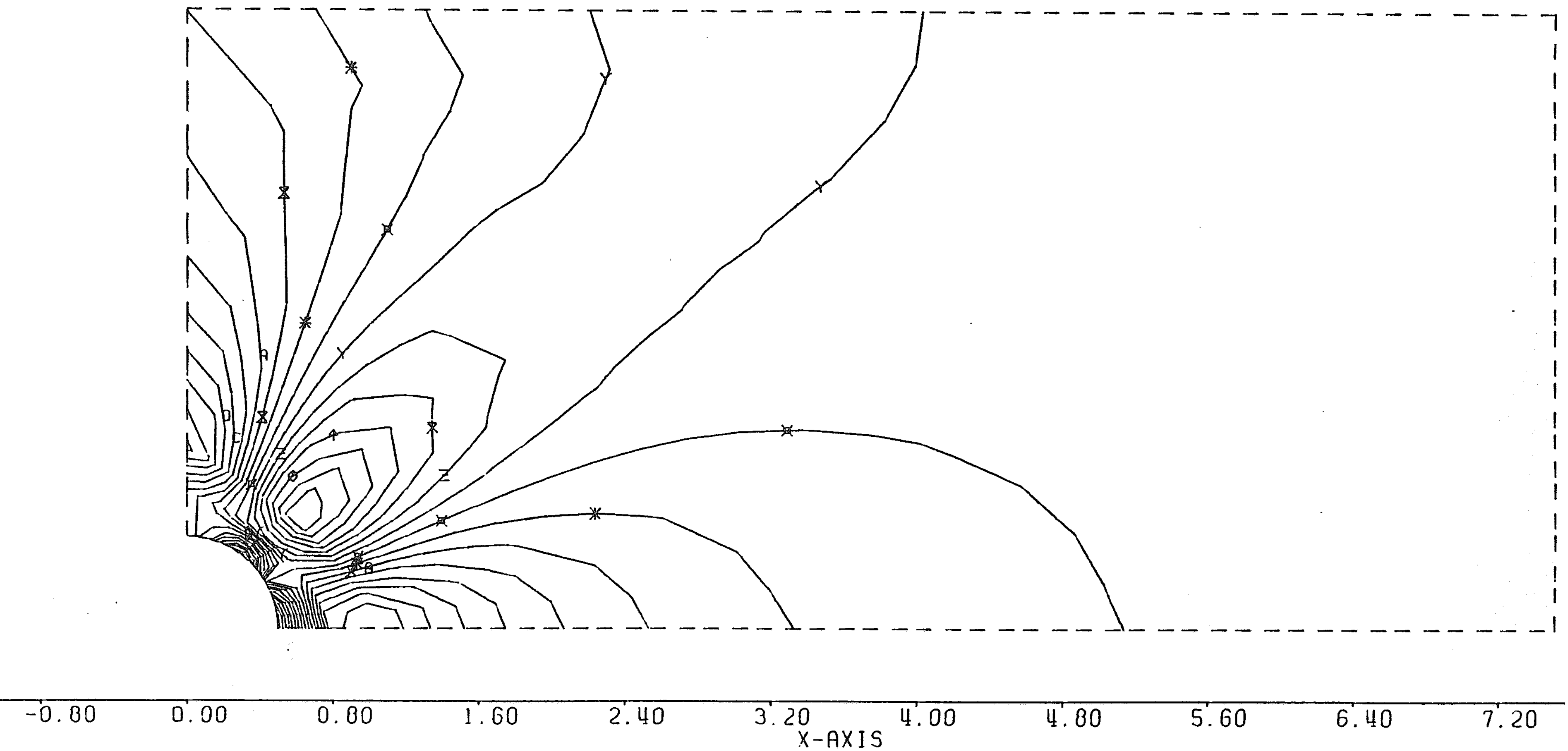
CONTOURS REQUESTED

⌽	.90958E+00
△	.96905E+00
+	.10285E+01
×	.10880E+01
◇	.11474E+01
↑	.12069E+01
⧗	.12664E+01
Z	.13258E+01
Y	.13853E+01
⌧	.14448E+01
✳	.15042E+01
⧖	.15637E+01
A	.16232E+01
B	.16826E+01
C	.17421E+01
D	.18016E+01
E	.18610E+01
F	.19205E+01
G	.19800E+01
H	.20394E+01

Task 6.3
AS 64 MP 361.5
9.21.82
KJM
D6 of 3

A564 MP3WS
9.21.82
KJM

HØLE IN FLANGE ØN YUKØN BRIDGE
SIGMAY STRESS CØNTØURS



HOLE IN FLANGE ON YUKON BRIDGE

TAUXY STRESS CONTOURS

CONTOURS REQUESTED

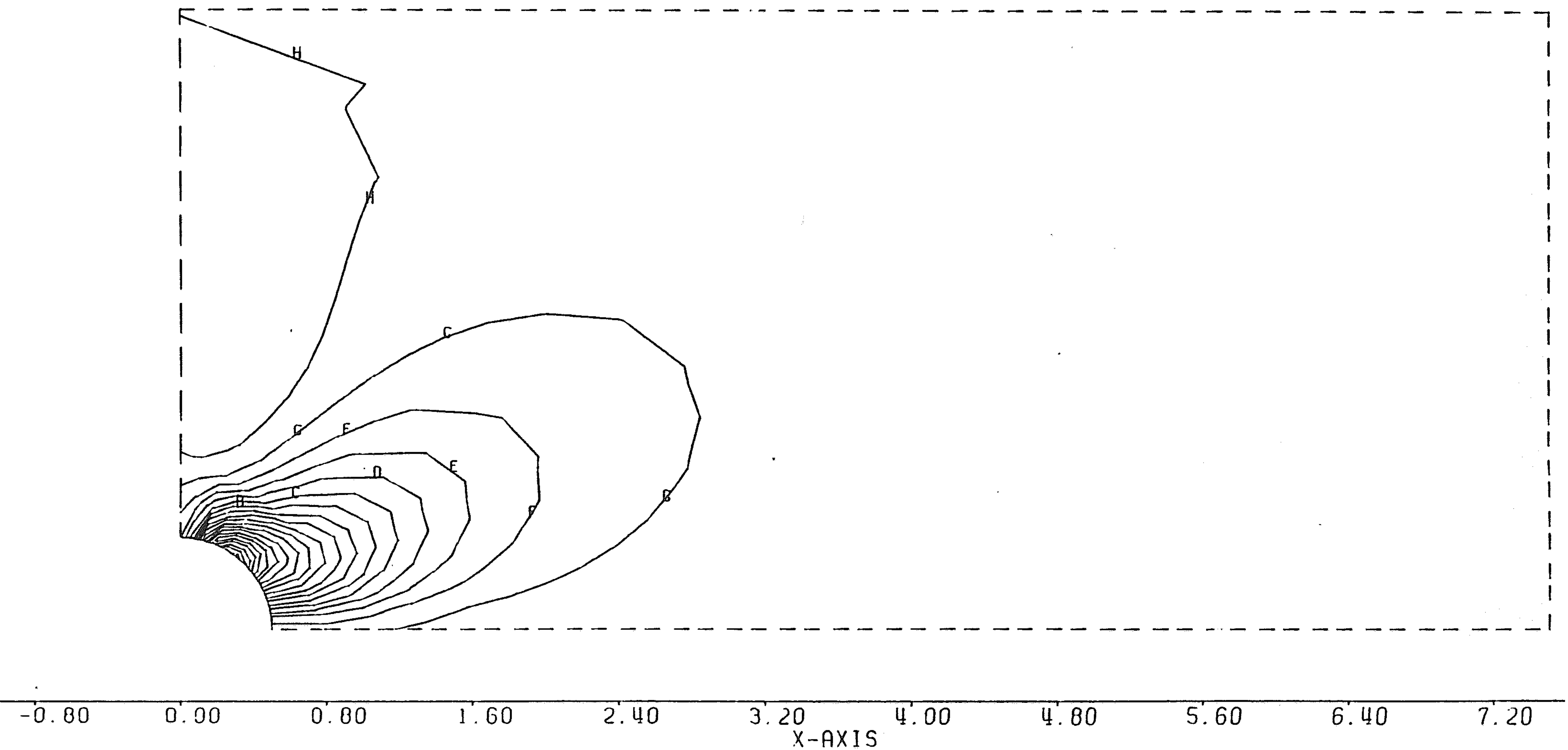
⦶	-.27222E+01
△	-.25787E+01
+	-.24351E+01
×	-.22916E+01
◇	-.21480E+01
↑	-.20045E+01
⧖	-.18610E+01
Z	-.17174E+01
Y	-.15739E+01
⌧	-.14303E+01
✳	-.12868E+01
⧖	-.11433E+01
A	-.99973E+00
B	-.85618E+00
C	-.71264E+00
D	-.56910E+00
E	-.42556E+00
F	-.28202E+00
G	-.13848E+00
H	.50575E-02

Task 63
AS64 MP 361.5
9 21 82
KJM
D8 of 3

Task 6.3
AS 64 MP 361.5
9.21.82
KJM
D9 of 13

HØLE IN FLANGE ØN YUKØN BRIDGE

TAUXY STRESS CØNTØURS



HOLE IN FLANGE ON YUKON BRIDGE
SIGMA1 STRESS CONTOURS

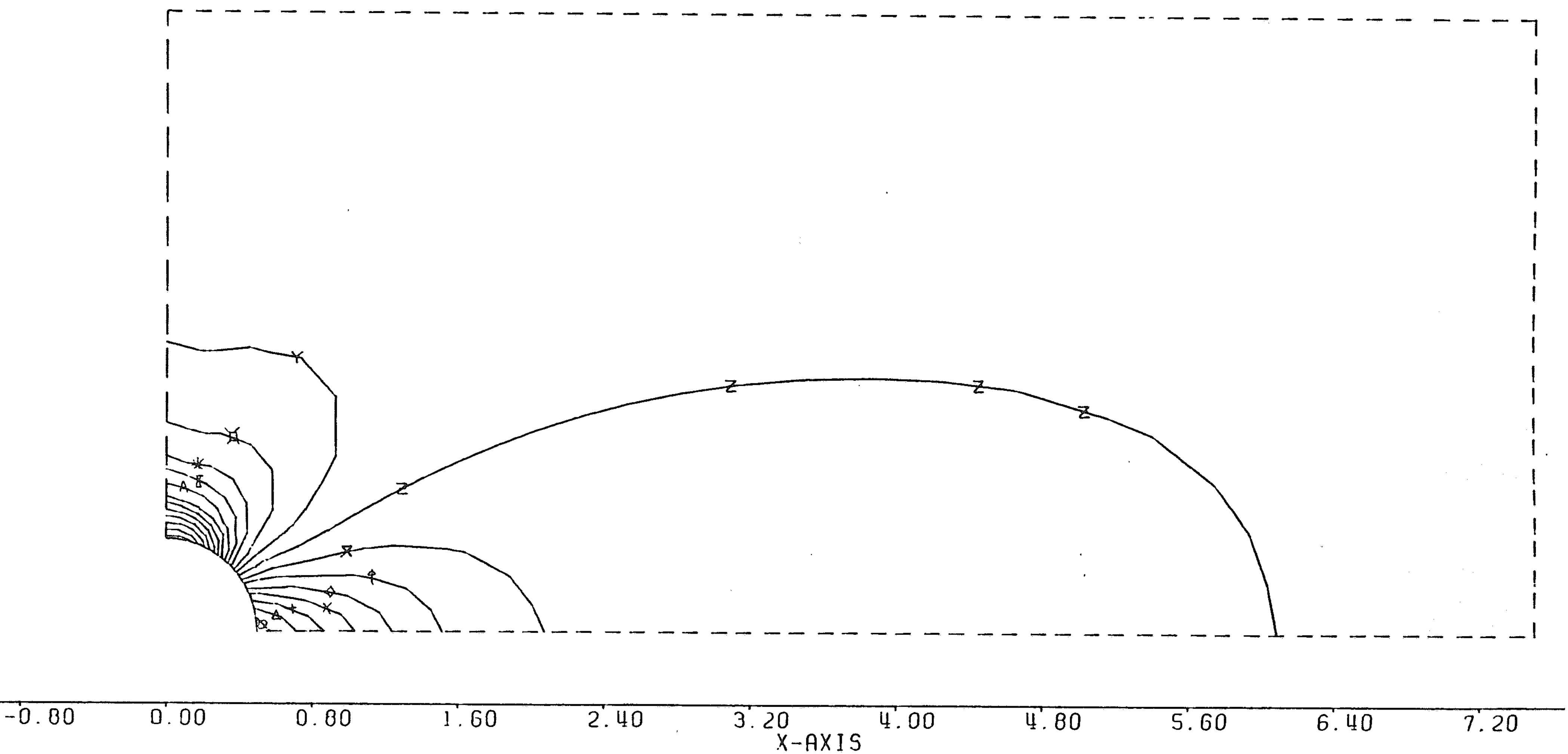
CONTOURS REQUESTED

⏀	.13452E+01
△	.18285E+01
+	.23118E+01
×	.27951E+01
◇	.32784E+01
↑	.37617E+01
⧖	.42451E+01
Z	.47284E+01
Y	.52117E+01
⌧	.56950E+01
✳	.61783E+01
⧖	.66616E+01
A	.71449E+01
B	.76282E+01
C	.81115E+01
D	.85949E+01
E	.90782E+01
F	.95615E+01
G	.10045E+02
H	.10528E+02

Task 6.3
AS 64 MP 361.5
9.21.82
KJM
D 10 of 13

HØLE IN FLANGE ØN YUKØN BRIDGE

SIGMA1 STRESS CØNTØURS



HOLE IN FLANGE ON YUKON BRIDGE

SIGMA2 STRESS CONTOURS

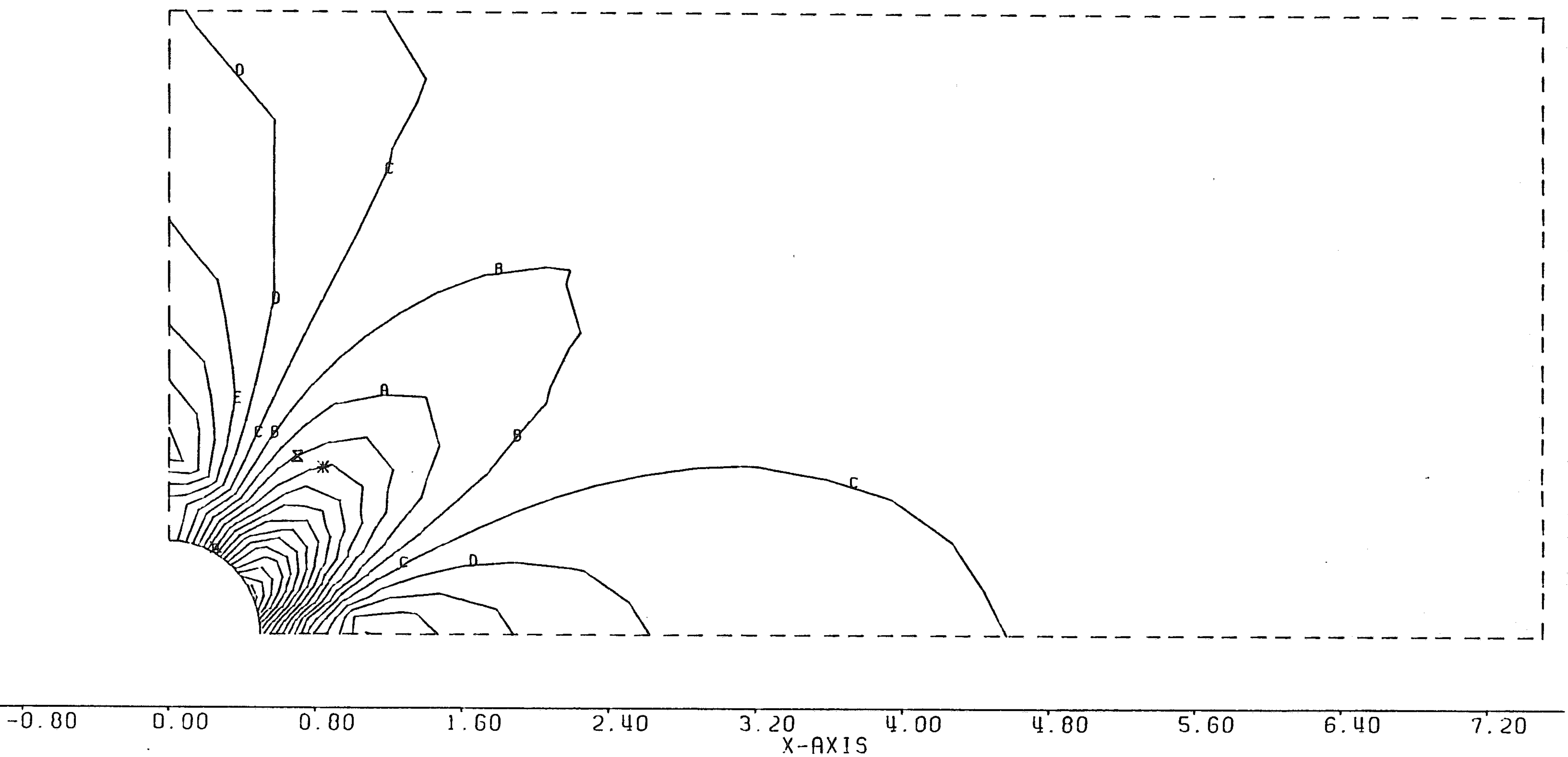
CONTOURS REQUESTED

⦶	.77501E-01
△	.17600E+00
+	.27450E+00
X	.37299E+00
◇	.47149E+00
↑	.56999E+00
⧗	.66849E+00
Z	.76699E+00
Y	.86548E+00
⌑	.96398E+00
✳	.10625E+01
⧖	.11610E+01
A	.12595E+01
B	.13580E+01
C	.14565E+01
D	.15550E+01
E	.16535E+01
F	.17520E+01
G	.18505E+01
H	.19490E+01

Task 6.3
AS 64 MP 361.5
9.21.82
KJM
D12 of 13

Task 6.3
AS 64 MP 361.5
4.21.82
KJM
D13 of 13

HOLE IN FLANGE ON YUKON BRIDGE
SIGMA2 STRESS CONTOURS



APPENDIX E

CALCULATION SHEETS

ANALYSIS OF PIPELINE FATIGUE

App'd KJ Meyer 9.30.82

GULF INTERSTATE ENGINEERING COMPANY — MICHAEL BAKER, JR., INC.

A Joint Venture

TASK NO. 52 TASK TITLE Special Design & Details - Yukon River Bridge

SUBJECT Gas Pipe Line - Fatigue Analysis SHEET NO. F1 of 13

ANSYS INPUT DATA FILE NO. 800

REV. NO. 0 BY EU DATE 5/24/82 CHKD. BY KJM DATE 9.21.82

- THE INFLUENCE LINE RESULTS FROM THE COMPUTER RUN "RO22ICBS" CONTAINED IN THE "STUDY OF PIPE PLACEMENT ON WEST PIPEWAY OF THE YUKON RIVER BRIDGE" REPORT, WAS USED TO OBTAIN THE CRITICAL LOCATIONS FOR LL (TRUCK) PLACEMENTS ALONG THE BRIDGE.
- TWO TRUCKS WERE USED AS SHOWN NEXT PG.
- THE FOLLOWING COMPUTER MODELS WERE USED

FATIGUE 1. 1) DL + LL + I (@ 1ST, 3RD, 5TH SPANS)

2) LL + I (@ 1ST, 3RD, 5TH SPANS)

FATIGUE 2. LL + I (@ 2ND, 4TH, 6TH SPANS)

FATIGUE 1A. LL + I (@ 1ST SPAN)

Note - FATIGUE 1A only used to check results for Alternative B. Found not critical

Form-JVE-2

FM-91-A-002

GULF INTERSTATE ENGINEERING COMPANY — MICHAEL BAKER, JR., INC.

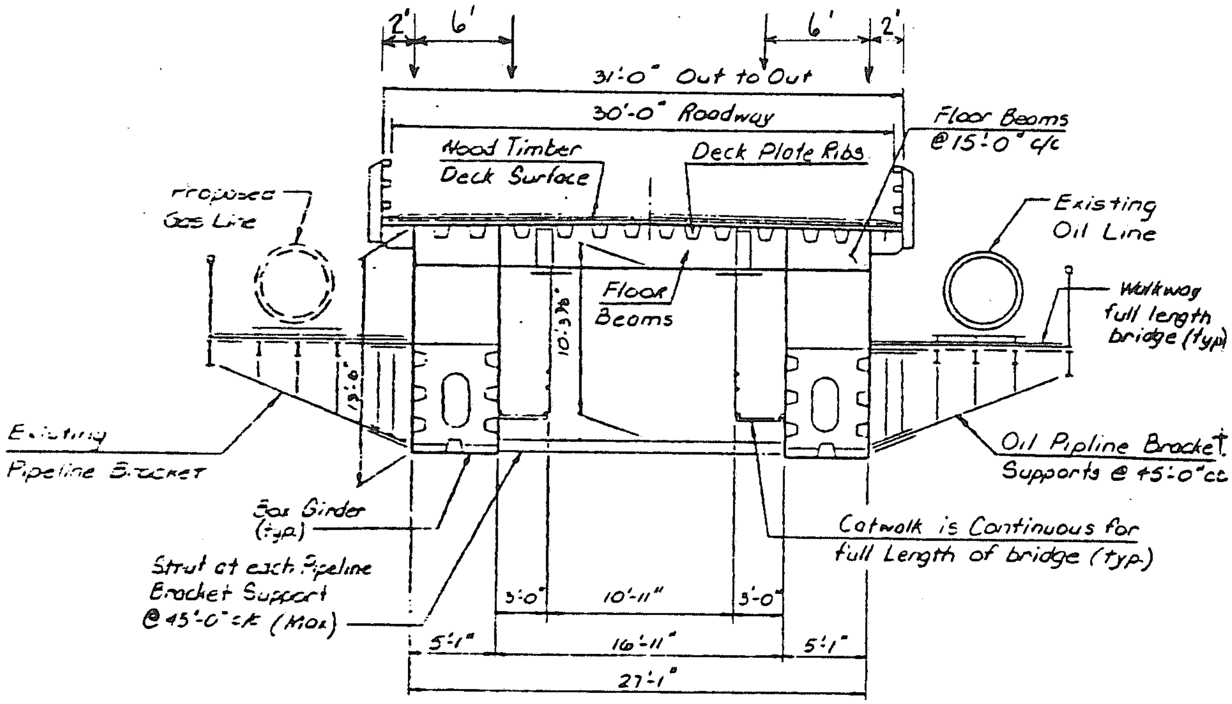
A Joint Venture

TASK NO. 52 TASK TITLE Special Design & Details - Yukon River Bridge

SUBJECT Gas Pipe Line - Fatigue Analysis SHEET NO. F2 of 13

Truck Location FILE NO. 800

REV. NO. 0 BY KJM DATE 9.22.82 CHKD. BY KJM DATE 9.25.82



TYPICAL SECTION AT OIL & GAS PIPELINE SUPPORT

2 - HS-20$_{44}$ Trucks

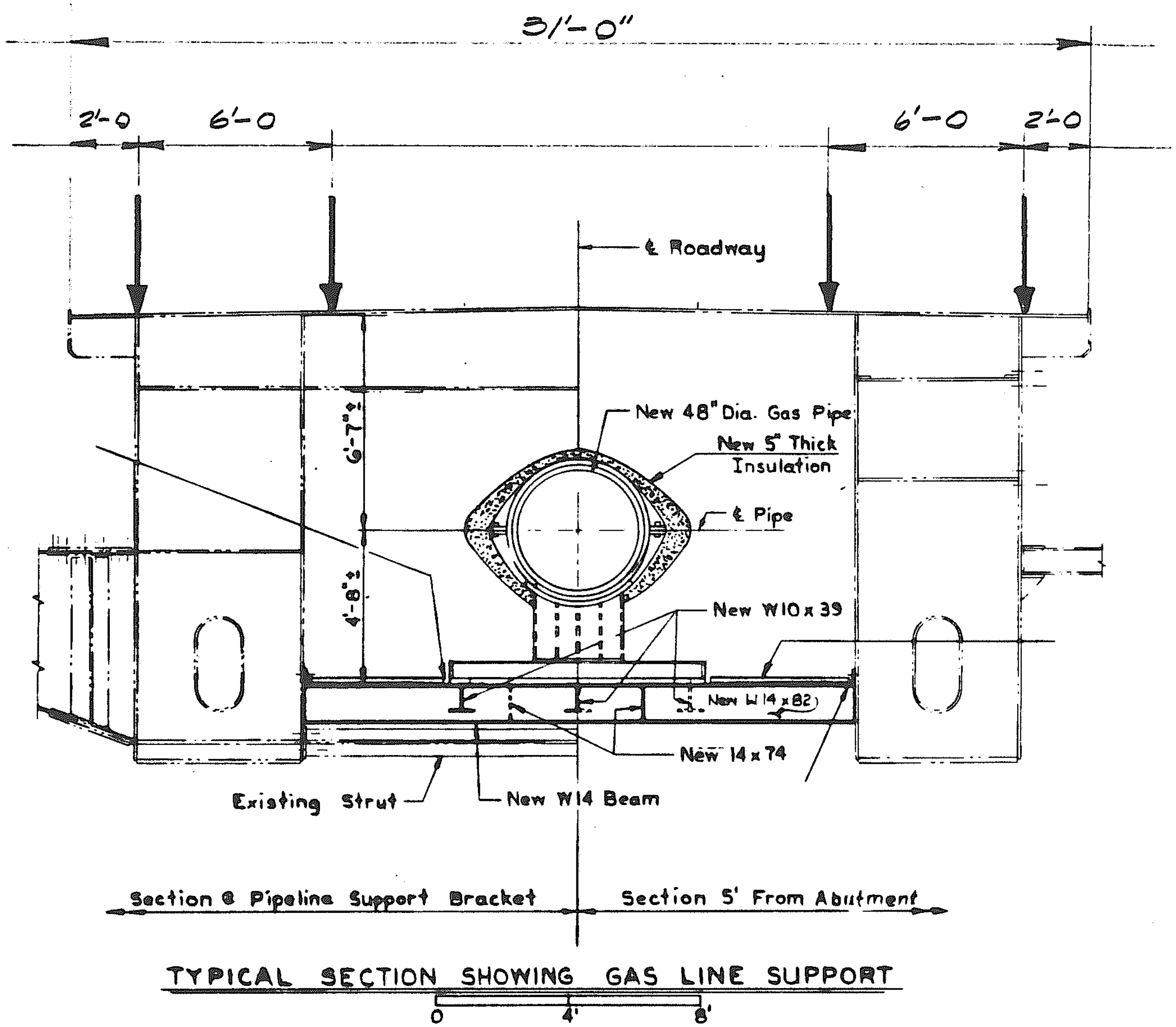
For Scheme A

Nodal loads for ANSYS as shown on shts F4 to F11

Form-JVE-2

FM-91-A-0

TASK NO. 52 TASK TITLE Special Design & Details - Yukon River Bridge
SUBJECT Gas Pipe Line - Fatigue Analysis SHEET NO. F3 of 13
Truck Location FILE NO. 800
REV. NO. 0 BY EU DATE 5/24/82 CHKD. BY KJM DATE 9.21.82



2 - HS-20$_{44}$ Trucks

For Scheme B

Nodal loads for ANSYS as shown on shts F4 to F11

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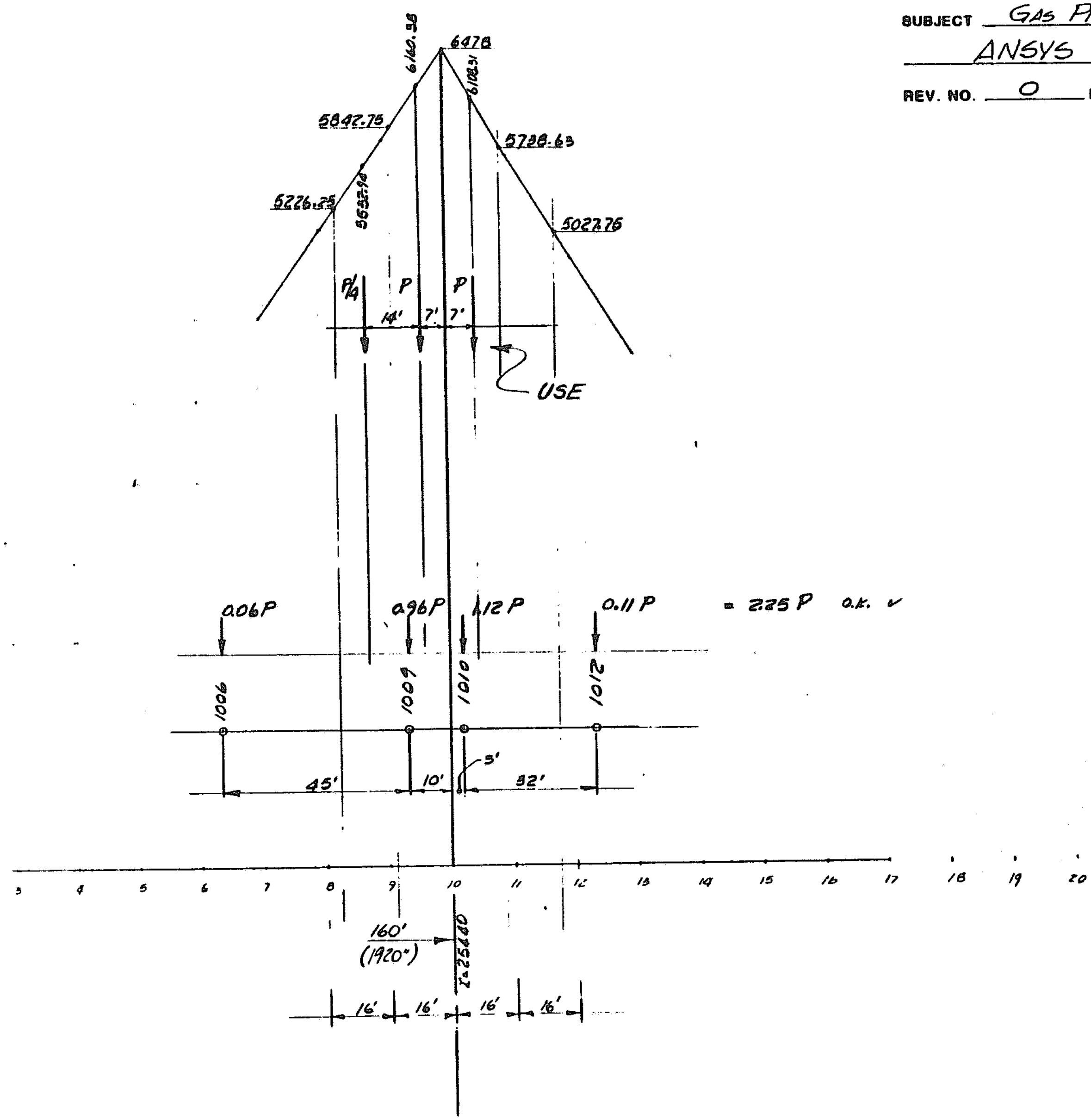
TASK NO. 52 TASK TITLE Special Design & Details - Yukon River Bridge

SUBJECT Gas Pipeline – Fatigue Analysis SHEET NO. F4 of 13

ANSYS INPUT DATA FILE NO. 800

REV. NO. 0 BY EU DATE 5/17/82 CHKD. BY KJM DATE 9.21.82

SPAN 1



1. 6478 + 5842.75 + 5226.25/4 = 13627.31

2. 6108.31 + 6160.38 + 5532.94/4 = 13651.93

THUS $M = 32"(13651.93/100)$

$\therefore M_{LL} = 4368.62^{1\text{-}k}$

$I = 50/(820+126) = 0.1124$

$M_{LL+I} = 1.1124 \times M_{LL}$

$M_{LL+I} = 4859.48^{1\text{-}k}$

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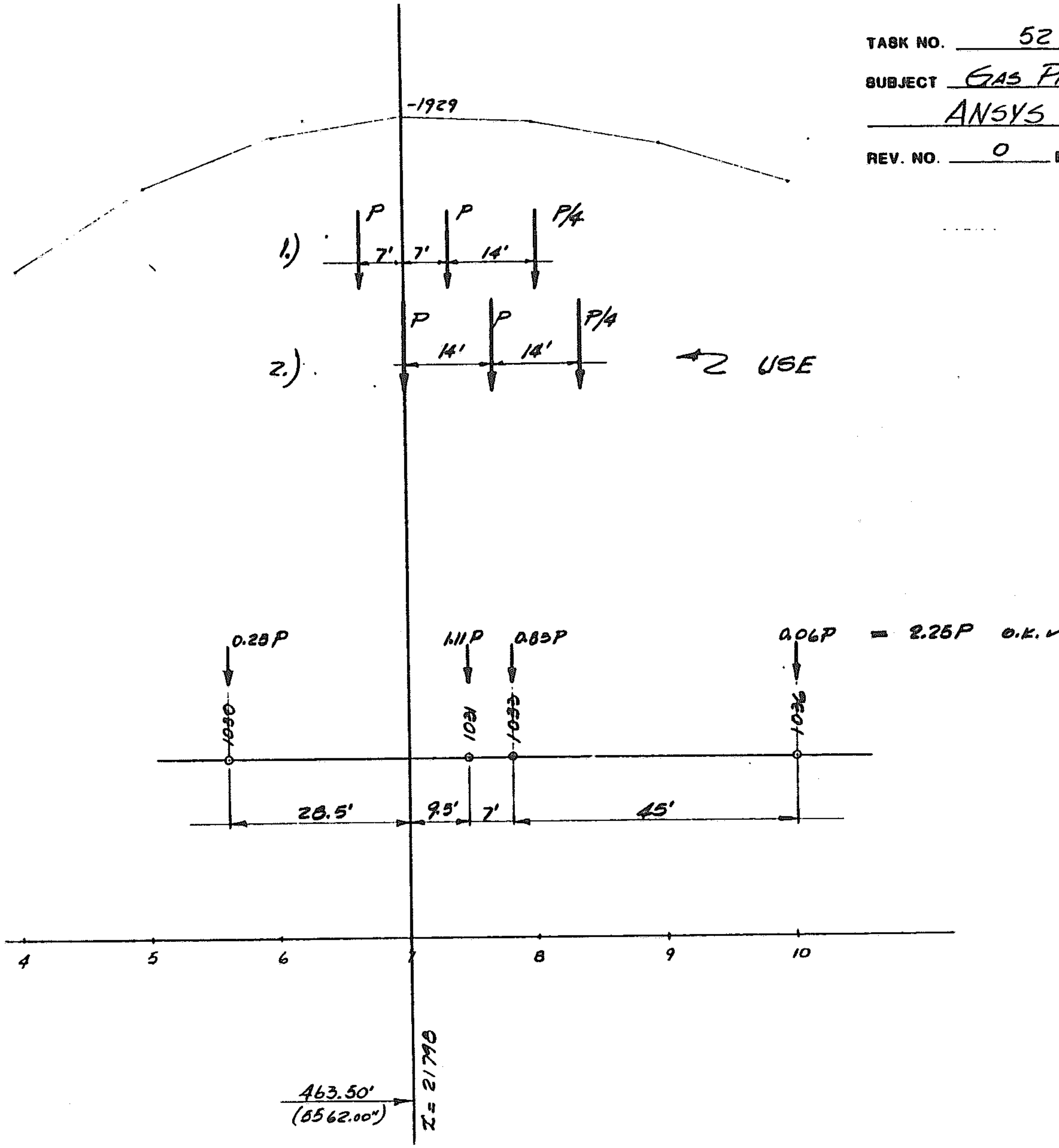
SPAN 2

TASK NO. 52 TASK TITLE Special Design & Details - Yukon River Bridge

SUBJECT Gas Pipeline - Fatigue Analysis SHEET NO. FS of 13

ANSYS INPUT DATA FILE NO. 800

REV. NO. 0 BY EU DATE 5/5/82 CHKD. BY KJM DATE 9.21.82



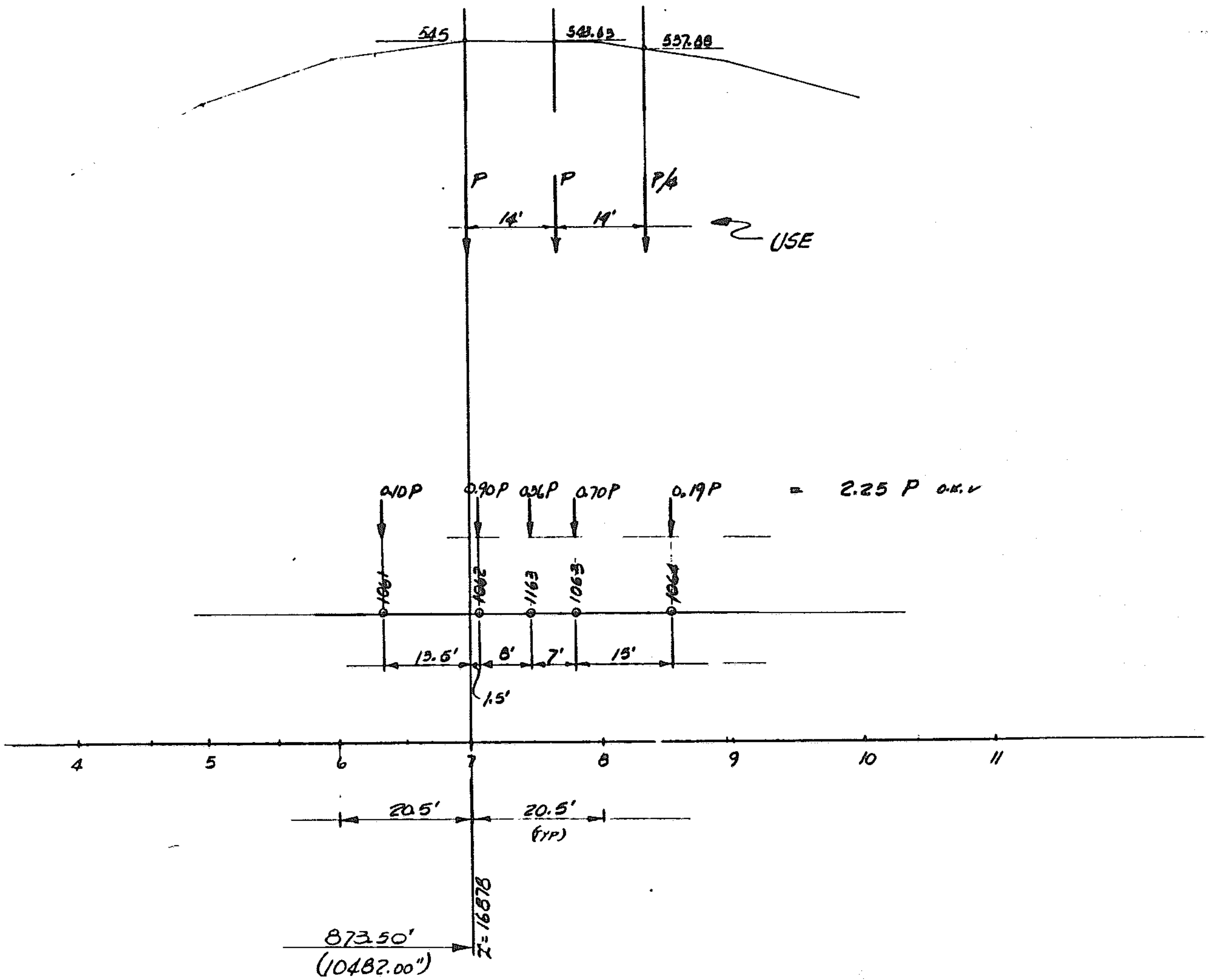
1. 1912.61 + 1924.90 + 1915.63/4 = 4316.42

2. 1929 + 1920.8 + 1896.51/4 = 4323.93

$$M_{LL+I} = (1.0935)(32)(4323.93/100)$$

$$M_{LL+I} = 1513.03^{\prime\text{-}K}$$

SPAN 3



1. $545 + 543.63 + 537.88/4 = 1223.10$

$I = 50/(410 + 125) = 0.0935$

$M_{LL+I} = (1.0935 \times 32)(1223.10)/100$

$M_{LL+I} = 427.97$ ᴵ⁻ᴷ

SPAN 4

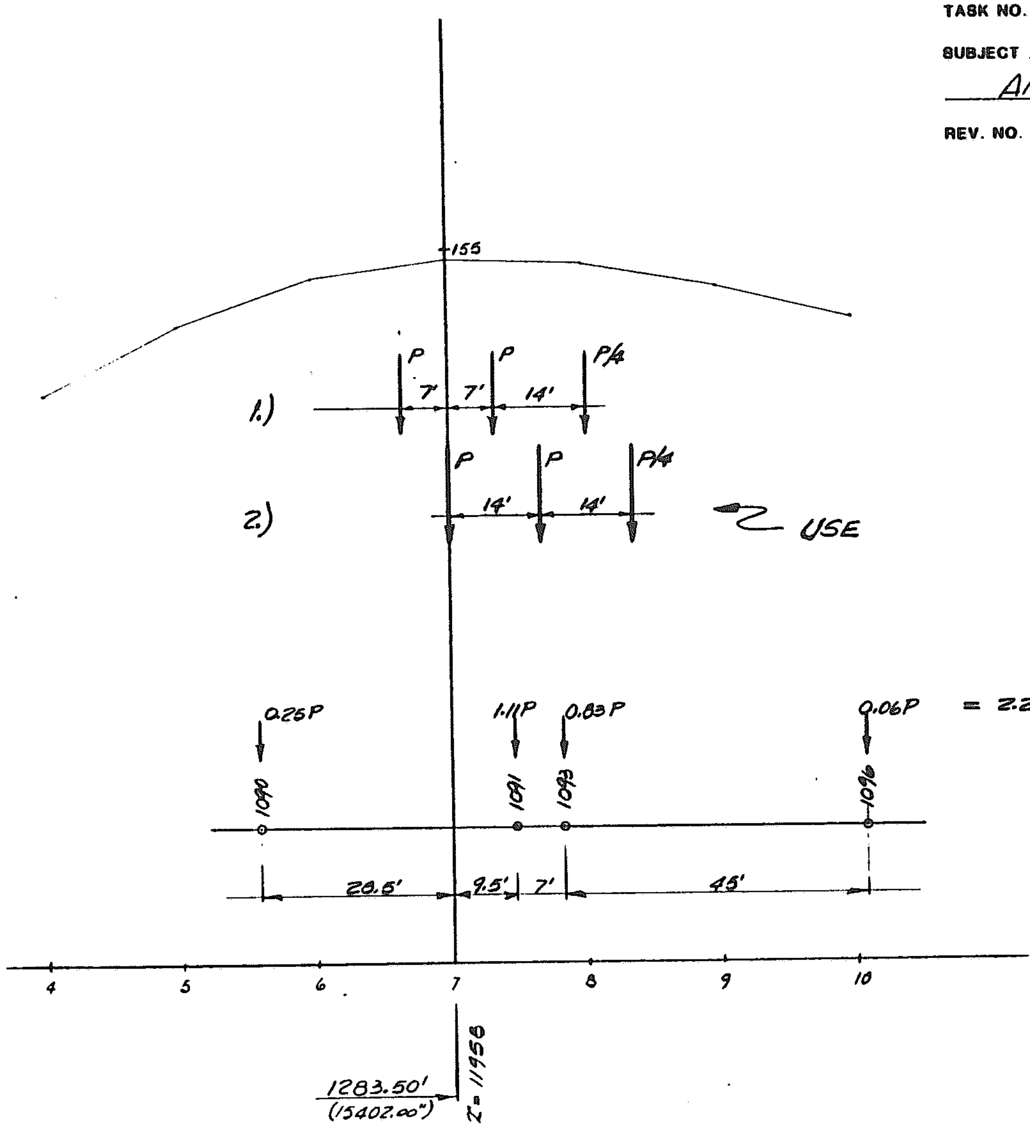
GULF INTERSTATE ENGINEERING COMPANY — MICHAEL BAKER, JR., INC. — A Joint Venture

TASK NO. 52 TASK TITLE Special Design & Details - Yukon River Bridge

SUBJECT Gas Pipeline - Fatigue Analysis SHEET NO. F7 of 13

ANSYS INPUT DATA FILE NO. 900

REV. NO. 0 BY EU DATE 9/3/82 CHKD. BY KJM DATE 9.21.82

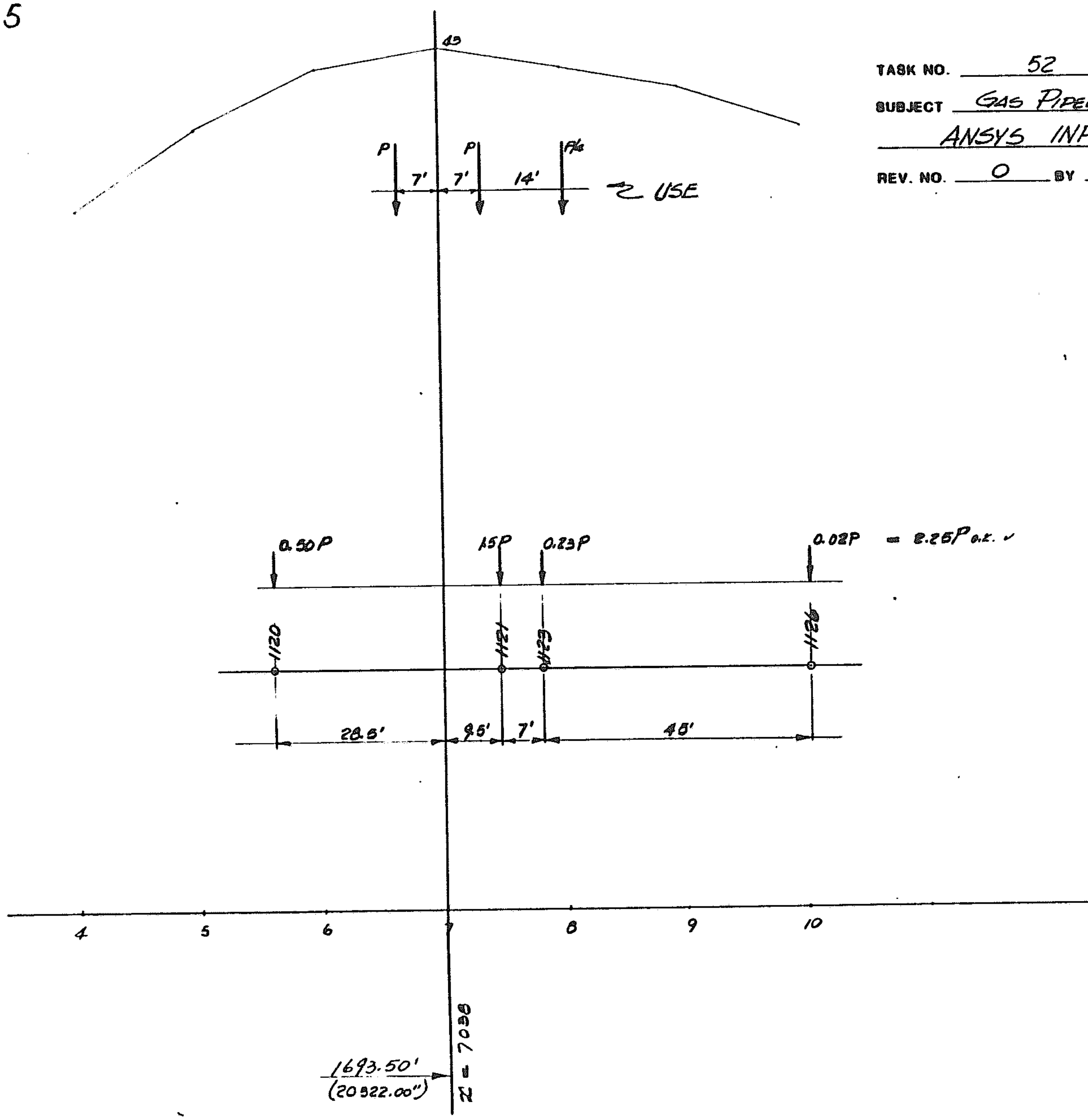


= 2.25P O.K. ✓

1. 153.63 + 154.66 + 153.18/4 = 346.76

2. 155 + 154.32 + 152.17/4 = 347.36

SPAN 5



1. $42.66 + 42.66 + 41.98/4 = 95.81$
2. $43.00 + 42.32 + 41.63/4 = 95.73$

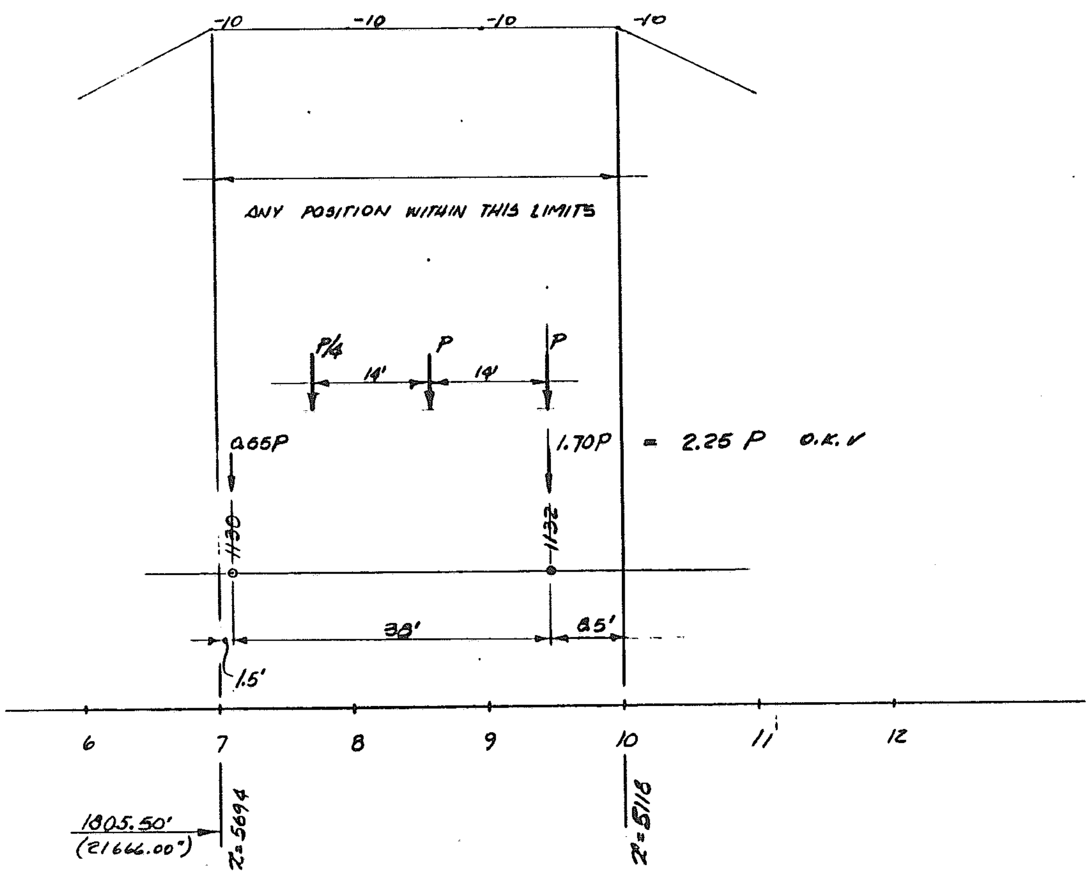
$$M_{LL+I} = (1.0935 \times 32)(95.81)/100$$

$$M_{LL+I} = 33.53 \ ^{1-k}$$

SPAN 6

GULF INTERSTATE ENGINEERING COMPANY — MICHAEL BAKER, JR., INC.

TASK NO. 52 TASK TITLE Special Design & Details - Yukon River Bridge
SUBJECT Gas Pipeline - Fatigue Analysis SHEET NO. F9 of 13
ANSYS INPUT DATA FILE NO. 800
REV. NO. 0 BY EU DATE 5/3/82 CHKD. BY KJM DATE 9.21.82



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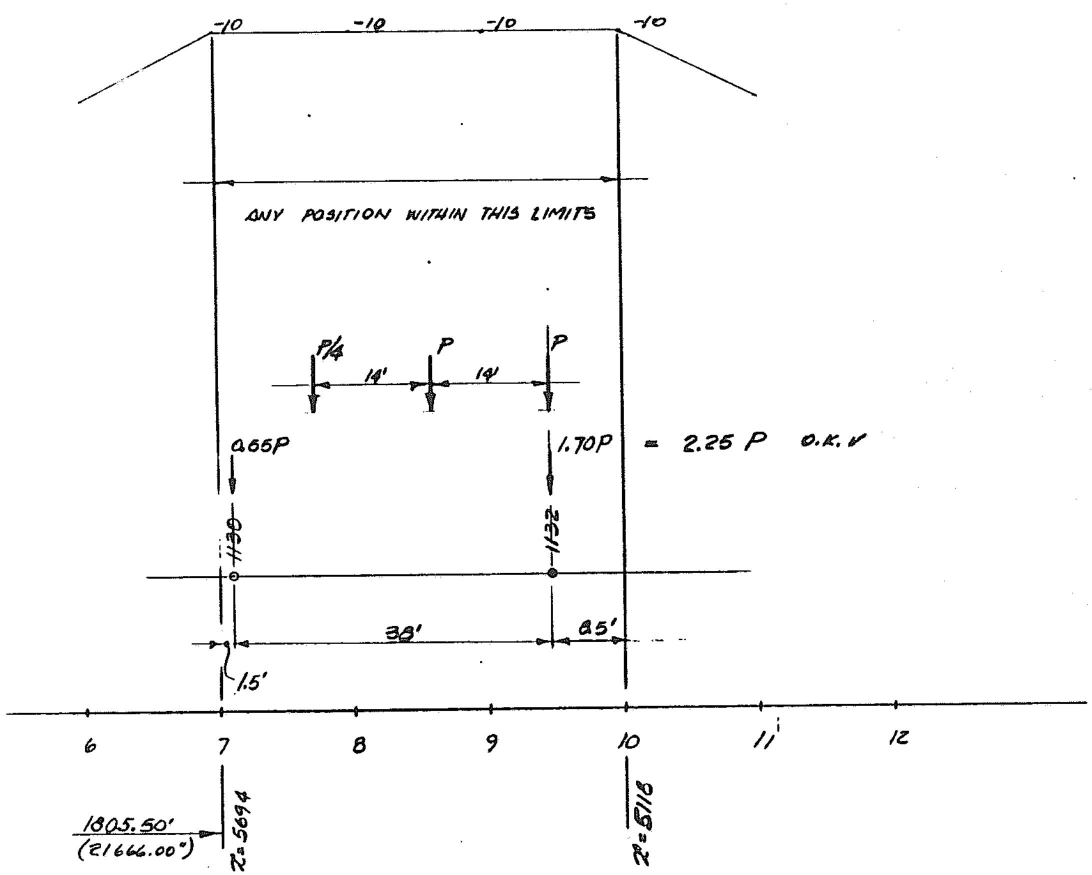
SPAN 6

TASK NO. 52 TASK TITLE SPECIAL DESIGN & DETAILS - YUKON RIVER BRIDGE
SUBJECT GAS PIPELINE - FATIGUE ANALYSIS SHEET NO. F9 of 13
ANSYS INPUT DATA FILE NO. 800
REV. NO. 0 BY EU DATE 5/3/82 CHKD. BY KJM DATE 9.21.82



CONCENTRATED LOADS PER NODES

SPAN 1 & 6

P = 32 x 1.1124 = 35.60^k

SPAN 2, 3, 4 & 5

P = 32 x 1.0935 = 34.99^k

SPAN 1, 3 & 5 FOR MAX. POSITIVE MOMENT @ 10/20 TH OF SPAN 1

1006, FY, -2.14 SAME ON 2000'S NODES
1009, FY, -34.18
1010, Fy, -39.87
1012, Fy, - 3.92 80.11/1.1124 = 72.02 O.K. ✓

1061, Fy, - 3.50 SAME ON 2000'S NODES
1062, Fy, - 31.49
1163, Fy, - 12.60
1063, Fy, - 24.49
1064, Fy, - 6.65 78.73/1.0935 = 72.00 O.K. ✓

1120, Fy, - 17.50 SAME ON 2000'S NODES
1121, Fy, - 52.49
1123, Fy, - 8.05
1126, Fy, - 0.70 78.73/1.0935 = 72.00 O.K. ✓

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TASK NO. 52 TASK TITLE SPECIAL DESIGN & DETAILS – YUKON RIVER BRIDGE

SUBJECT GAS PIPELINE – FATIGUE ANALYSIS SHEET NO. F11 of 13

ANSYS INPUT DATA FILE NO. 800

REV. NO. 0 BY EU DATE 5/18/82 CHKD. BY KJM DATE 9.21.82

SPAN 2, 4 & 6

1030 , Fy , – 8.75 SAME ON 2000'S NODES

1031 , Fy , – 38.84

1033 , Fy , – 29.04

1036 , Fy , – 2.10 78.73/1.0935 = 72.00 O.K. ✓

1090 , Fy , – 8.75 SAME ON 2000'S NODES

1091 , Fy , – 38.84

1093 , Fy , – 29.04

1096 , Fy , – 2.10 78.73/1.0935 = 72.00 O.K. ✓

1130 , Fy , – 19.58 SAME ON 2000'S NODES

1132 , Fy , – 60.52 80.10/1.1124 = 72.01 O.K. ✓

Form-JVE-2

FM-91-A-002

TASK NO. 52 TASK TITLE Special Design & Details - Yukon River Bridge

SUBJECT Gas Pipe Line - Fatigue SHEET NO. F12 of 13

Range of Stresses FILE NO. 800

REV. NO. 0 BY KJM DATE 9.22.82 CHKD. BY KJM DATE 9.25.82

From Computer Outputs: (Alternative A - Pipe on west pipeway)

Max. Displacements

From Node no.	Fatigue 1	Fatigue 2	Range
132	+1.41"	-1.95"	3.36"
133	+1.50	-2.00	3.50
134	+1.46	-1.78	3.24
142	-2.25	+1.16	3.41
143	-2.28	+1.23	3.51 ←
144	-2.02	+1.19	3.21

Max range of stresses

From Elem no.	Fatigue 1	Fatigue 2	Range
471	+1.95 Ksi	-0.79 Ksi	2.74 Ksi ←
474	+0.64	-0.17	0.81
475	+0.87	-0.23	1.10
476	+0.88	-0.40	1.28

∴ Max. Fatigue range of stresses (@ Node 121)

$$\sigma_R = 2.74^{\text{Ksi}}$$

TASK NO. 52 TASK TITLE Special Design & Details - Yukon River Bridge
SUBJECT Gas Pipeline - Fatigue Analysis SHEET NO. F13 of 13
Range of Stresses FILE NO. 800
REV. NO. 0 BY EU DATE 5/19/82 CHKD. BY KJM DATE 9.21.82

From Computer Outputs: (Alternative B - Pipe beneath deck)

Max. Displacements

From Node No	Fatigue 1	Fatigue 2	Range
942	-2.23"	+0.83"	3.06"
943	-2.26	+0.83	3.09
944	-2.01	+0.75	2.75
932	+1.40	-1.85	3.25
933	+1.49	-1.87	3.36 ←
934	+1.45	-1.65	3.10

Max. Range of Stresses

From	Fatigue 1	Fatigue 2	Range
594	0.32 ksi	0.84 ksi	1.16 ksi
595	0.32	0.85	1.17
585	2.40	0.91	3.31 ←
604	0.95	0.22	1.17

∴ Max. Fatigue Range of Stresses (@ Node 918)

$$\sigma_R = 3.31 \text{ ksi}$$

Appd KJ Meyer 9-21-82

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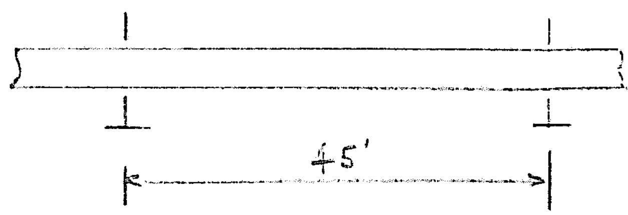
TASK NO. 52 TASK TITLE Special Pipeline Design- Yukon River Bridge

SUBJECT Pipeline Design Review SHEET NO. B1 of 3

AS 64 MP 261.5 FILE NO. 61.1

REV. NO. 0 BY KJM DATE 9-20-82 CHKD. BY KJM DATE 9-21-82



48, #0.72" pipe

Assume fixed - fixed conditions

$$I = \frac{\pi}{64}\left(48^4 - 46.56^4\right) = 29890 \text{ in}^4$$

$$wt = \underset{\text{(steel)}}{364 \text{ lb/ft}} + \underset{\text{(insulation)}}{38 \text{ lb/ft}} + \underset{\text{(gas wt)}}{80 \text{ lb/ft}} = 482 \text{ lb/ft}$$

$E = 30 \times 10^6$ psi

$g = 386$ in/sec²

$$\text{frequency} = 3.56 \sqrt{gEI / wt\, L^4}$$

$$= 3.56 \sqrt{\frac{386 \times 30000000 \times 29890 \times 12}{482 \times (45 \times 12)^4}}$$

$$= 35.84 \text{ sec}^{-1}$$

For simply supported conditions $f = 1.57\sqrt{\frac{gEI}{wt\,L^4}} = \frac{1.57}{3.56}\, 35.84 = 15.81 \text{ sec}^{-1}$

(Eq. from Dynamics of Vibrations, Volterra & Zachmanoglou, Charles Merrill Books 1965)

Form-JVE-2

FM-91-A-002

Thus, simply supported conditions will provide a frequency closer to the natural frequency of the bridge and will be more conservative.

It can be shown that the frequency equation for a continuous span beam will yield similar results: "...for any number of identical spans with hinges at exterior supports, the fundamental mode is the same as for a single, simply supported span" (*Introduction to Structural Dynamics*, John Biggs, McGraw Hill 1964)

Any increase in restraint such as that afforded by the pipe shoes would serve to increase the overall system stiffness and, thus, raise the frequency.

Conclusion: Use frequency of simply supported beam $= 15.8 \text{ sec}^{-1}$

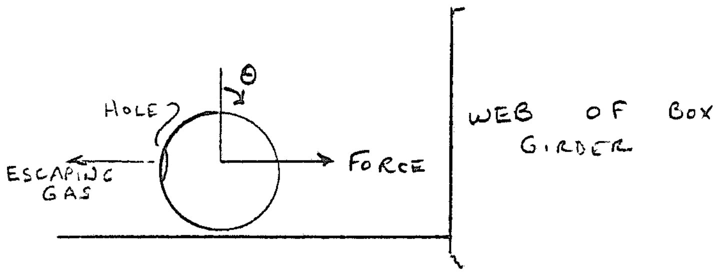
APPENDIX F

CALCULATION SHEETS

ANALYSIS OF EFFECTS OF POSTULATED HOLE IN THE PIPELINE

TASK NO. 52 TASK TITLE Special Pipeline Design - Yukon River Bridge
SUBJECT Technical Concerns SHEET NO. C1 of 20
As 64 MP 361.5 FILE NO. 61.1
REV. NO. 0 BY KJM DATE 9-20-82 CHKD. BY ____ DATE ____

EFFECT OF HOLE IN PIPELINE



LOOKING S TO N

FIND CRITICAL FORCE FOR

1) HOLE ON BOTTOM OF PIPE
FORCE APPLIED AT θ = 0°, VERTICALLY UP

2) HOLE ON TOP OF PIPE
FORCE APPLIED AT θ = 180°, VERTICALLY DOWN

3) HOLE ON OUTSIDE OF BRIDGE FACE
FORCE APPLIED AT θ = 90°, HORIZONTALLY TOWARD BRIDGE

4) HOLE ON INSIDE BRIDGE FACE
FORCE APPLIED AT θ = 270°, HORIZONTALLY AWAY FROM BRIDGE

CASE 1) VERTICALLY UP FORCE

MODE OF FAILURE: INSTABILITY BY OVERCOMING GRAVITY

SUPPOSE HOLE OCCURS AT A SUPPORT. THIS IS CRITICAL SINCE BETWEEN SUPPORTS THE EFFECT ON THE REACTION WOULD BE SHARED BY ADJACENT SUPPORTS

SUPPORT SPACING = 45'

wt/ft for 0.72" wh pipe = 364 lb/ft (steel) + 38 lb/ft insulation = 402 lb/ft

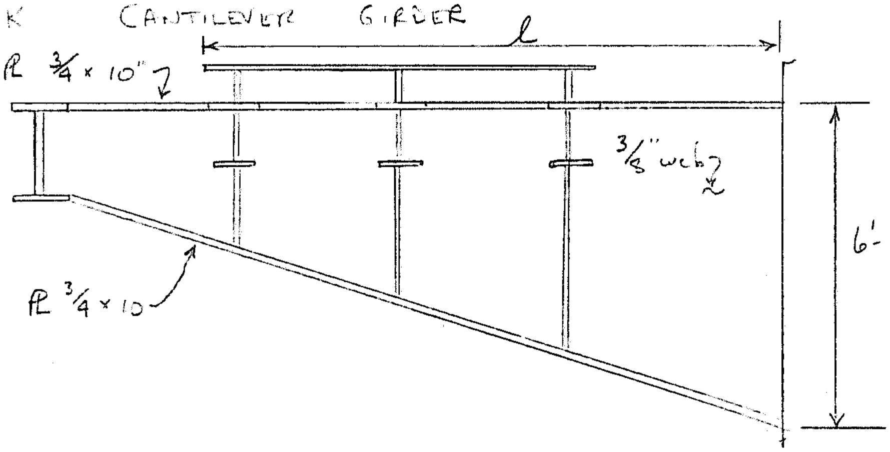
Reaction = 18.1^K

Conclusion: 18.1^K conservatively used for pipe instability
No bridge damage potential at this value.

CASE 2) VERTICALLY DOWN FORCE

SUPPOSE HOLE OCCURS AT A SUPPORT. THIS IS CRITICAL SINCE BETWEEN SUPPORTS THE EFFECT WOULD BE SHARED BY ADJACENT SUPPORTS

CHECK CANTILEVER GIRDER



Effect is maximized when l is maximized this occurs @ Nodes 22 (first pipe node on N side of bridge)

$l = 11'\text{-}10\frac{3}{4}''$

$$I = \frac{bd^3}{12} + 2A\left(\frac{d}{2}\right)^2 = \frac{3/8\,(72)^3}{12} + 2(10 \times .75)\left(\frac{72}{2}\right)^2$$

$$= 11664 + 19440 = 31104 \text{ in}^4$$

$$S = \frac{I}{c} = \frac{31104}{36} = 864 \text{ in}^3$$

Then allowable moment = $S\sigma$ = 864 × σ_{YLD}

= 864 × 50 ksi = 43200 K-in

Assume pipe is at extreme edge. If shoe is 3 feet wide then concentrated load + pipe static wt is at 10'-4¾"

Existing DL = 3/8" × $\left(\frac{15+6}{2}\right)$ × 15.2' × 144 × .283 (web of cantilever)
+ 2 × 3/4" × 15.2' × 10" × 12 × .283 (flgs. of cantilever)
+ 50 lb/ft × 45' (edge beam)
+ 1" × 66" × 91" × .283 (support plate)
+ 2000 lb (pipe shoe)
+ 24 × 10' × 45' (grating)
+ 165 lb/ft × 45' (protective cover)
+ 482 lb/ft × 45' (pipe + insulation wt)

= 871 + 774 + 2250 + 1700
+ 2000 + 10800 + 7425 + 21690
= 47.5^K

Moment = (871 + 774) × 7' + 2250 × 15.2' + 1700 × 8'
+ 2000 × 10.4 + 10800 × 8' + 7425 × 15.2'
+ 21690 × 10.4

= 504951 #-' = 505 K-' = 6060 K-in

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TASK NO. 52 TASK TITLE SPECIAL PIPELINE DESIGN - YUKON RIVER BRIDGE

SUBJECT TECHNICAL CONCERNS SHEET NO. C5 of 20

AS 64 MP 361.5 FILE NO. 61.1

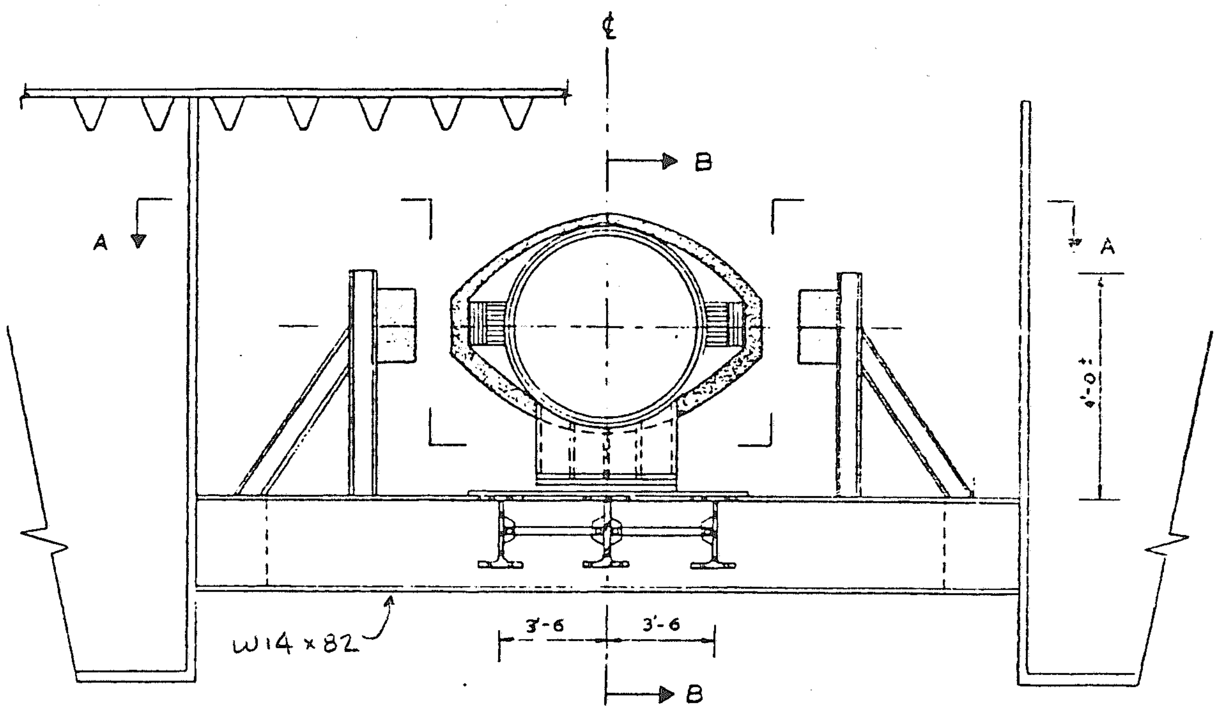
REV. NO. 0 BY KJM DATE 9/27/82 CHKD. BY ____ DATE ____

Then residual = 43200 - 6060 = 37140 $^{k\text{-}in}$

Then max possible concentrated load = $\frac{37140}{124.75}$ = 298^{k}

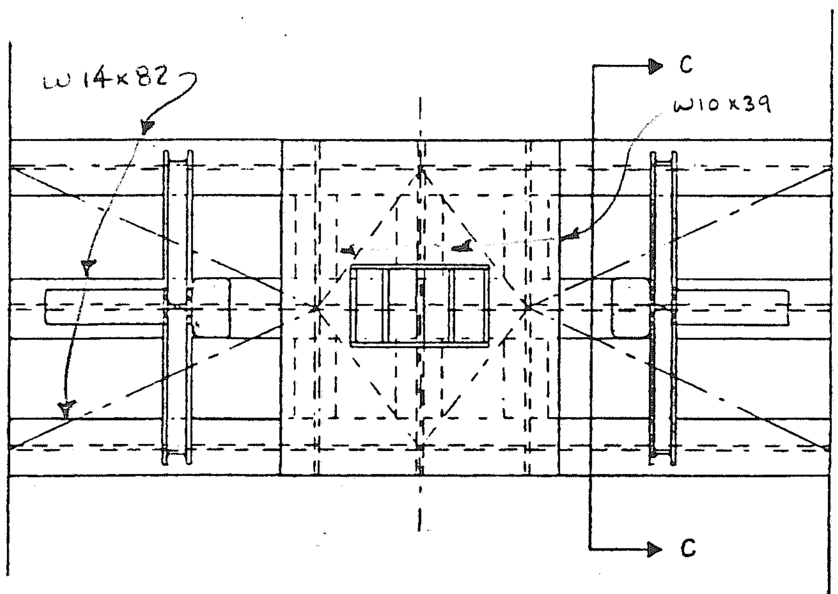
Check support frame for case where pipeline is supported under deck.

Note: Based on preliminary sizing of members:



ELEVATION

TASK NO. 52 TASK TITLE Special Pipeline Design - Yukon River Bridge
SUBJECT Technical Concerns SHEET NO. C6 of 20
AS 64 MP 361.5 FILE NO. 61.1
REV. NO. 0 BY KJM DATE 9/27/82 CHKD. BY ______ DATE ______



SECTION A-A

Assume central beam (W14x82) takes ½ of all load and takes full concentrated "leak" load.

Existing DL = ½ × 482 × 60' (pipe + insulation wt)
+ 17' × 82 + ½ × 3 × 10' × 39 + ½ × 12.8#/' × 53 LF (beams, angles)
+ ½ × 2 × 82 × 60' + ½ × 17' × 60' × 10#/□' (walkway + support)
+ .283 × ½ × 120" × 96" × 1" (plate) + 2000lb (shoe)

= 14460 + 1394 + 585 + 339 + 4920 + 5100
+ 1630 + 2000 = 30.4K

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TASK NO. 52 **TASK TITLE** Special Pipeline Design - Yukon River Bridge

SUBJECT Technical Concerns **SHEET NO.** [illegible]7 of 20

AS 64 MP 361.5 **FILE NO.** [illegible]

REV. NO. 0 **BY** KIM **DATE** 9/28/92 **CHKD. BY** ______ **DATE** ______

Existing Moment $= \frac{17'}{8}(14460 + 585 + 339 + 4920 + 2000 + 1630)$

$+ \frac{17'}{12}(1394 + 5100)$

$= 50860 + 9200 = 60060^{\#-'}$

$= 60.1^{k-'} = 721^{k-in}$

S of W14×82 = 130 in³

Allowable moment = 130 × 50 = 6500 k-in

Residual = 6500 − 721 = 5779 k-in

Then max possible concentrated load = $\frac{5779 \times 8}{17'} = 2720^k$

∴ Cantilever bracket for Alternative A is critical

at 298k

Now find effect of load on main girder:

The effect of the load should be maximum for the case where it is on the west pipeway as opposed to under the deck (where the box girders would share the effect).

Two ANSYS runs were made

1) With a concentrated load of 10^K vertically down at the node 43 (143 in ANSYS) which is in center of center span

2) With a concentrated load of 10^K vertically down at the node 72 (172 in ANSYS) which is at a plate transition area and which was critical point in the strengthening analysis.

Runs were done for configuration of one oil line + gas line on west pipeway.

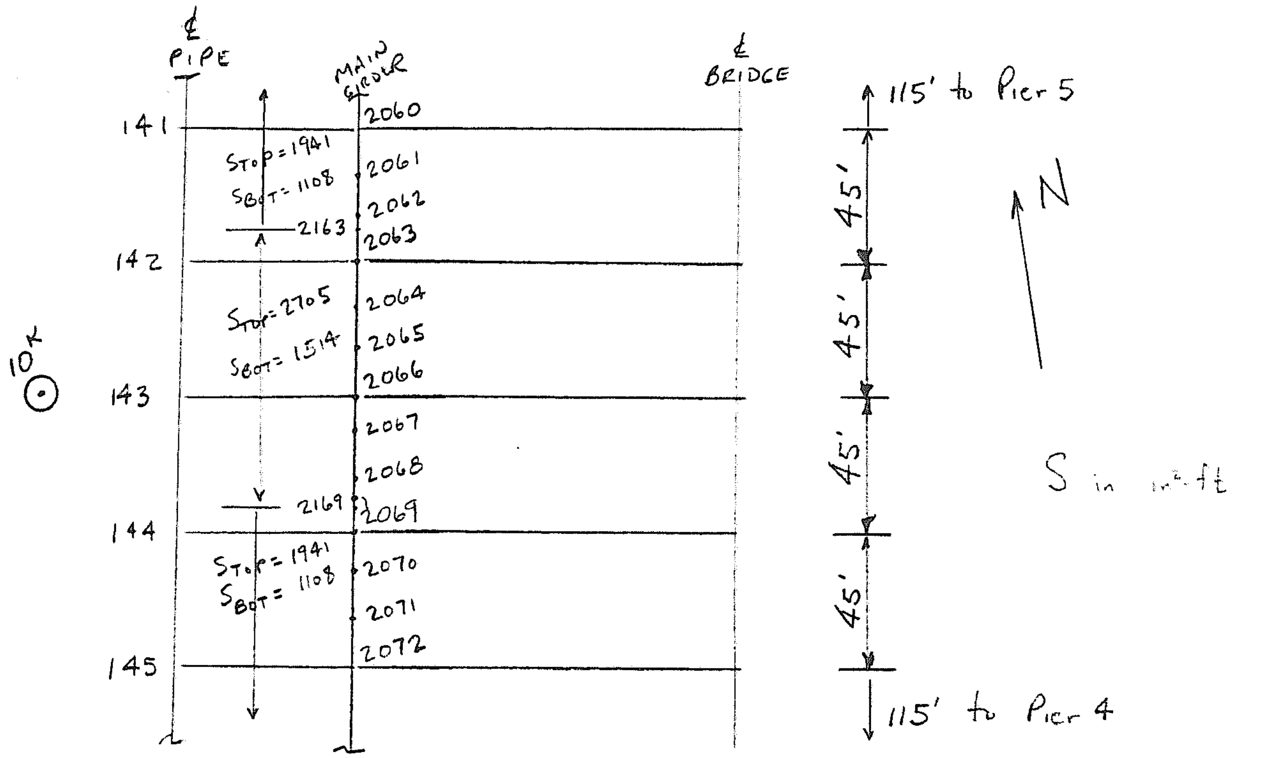
Moments monitored in girder closest to gas line. This is not the most loaded girder under DL but would be under the postulated break.

TASK NO. 52 TASK TITLE Special Pipeline Design - Yukon River Bridge

SUBJECT Technical Concerns SHEET NO. C9 of 20

AS 64 MP 361.5 FILE NO. 61.1

REV. NO. 0 BY KJM DATE 9/27/82 CHKD. BY ______ DATE ______



PT	K-" D.L. moment (w/operating gas line)	K-" D.L + 10K vertical	K-" Δ	Ksi $\Delta\sigma_{BOT}$
2060	-105064	106244	1180	0.09
2061	152585	154296	1711	0.13
2062	193309	195558	2249	0.17
2163	211814	214416	2602	0.20/0.14
2063	227040	229858	2818	0.16
2064	248525	251943	3418	0.19
2065	262576	266688	4112	0.23
2066	269105	274043	4938	0.27
2067	262926	267080	4154	0.23
2068	249190	252675	3485	0.19
2069	227869	230774	2905	0.16
2169	213091	215704	2613	0.14/0.20
2070	194094	196456	2362	0.18
2071	153046	154905	1859	0.14
2072	104764	106146	1382	0.10

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TASK NO. 52 TASK TITLE Special Pipeline Design - Yukon River Bridge

SUBJECT Technical Concerns SHEET NO. 10 of 20

AS 64 MP 361.5 FILE NO. 61.1

REV. NO. 0 BY KJM DATE 9/27/82 CHKD. BY ____ DATE ____

Assume Truck loading + Impact

At load point (midpoint of span = 2066)

Moment Truck Loading = 6159 K-ft

DL moment (w/o 10^k load) = 22425 K-ft

Thus existing σ = (22425 + 6159) / 1514 = 18.88 Ksi

Remaining to yield = 50 - 18.88 = 31.12 Ksi

Load to yield = $\frac{31.12}{0.27} \times 10^K$ = 1153^K

At transition point (2169)

Moment Truck Loading = 5574 K-ft

DL moment (w/o 10^k load) = 213091/12 K-" = 17758 K-'

Existing σ = (5574 + 17758) / 1108 = 21.06 Ksi

Remaining to yield = 50 - 21.06 = 28.94 Ksi

Load to yield = $\frac{28.94}{0.20} \times 10^K$ = 1447^K

Critical analysis point is load point, __1153^K__ to yield

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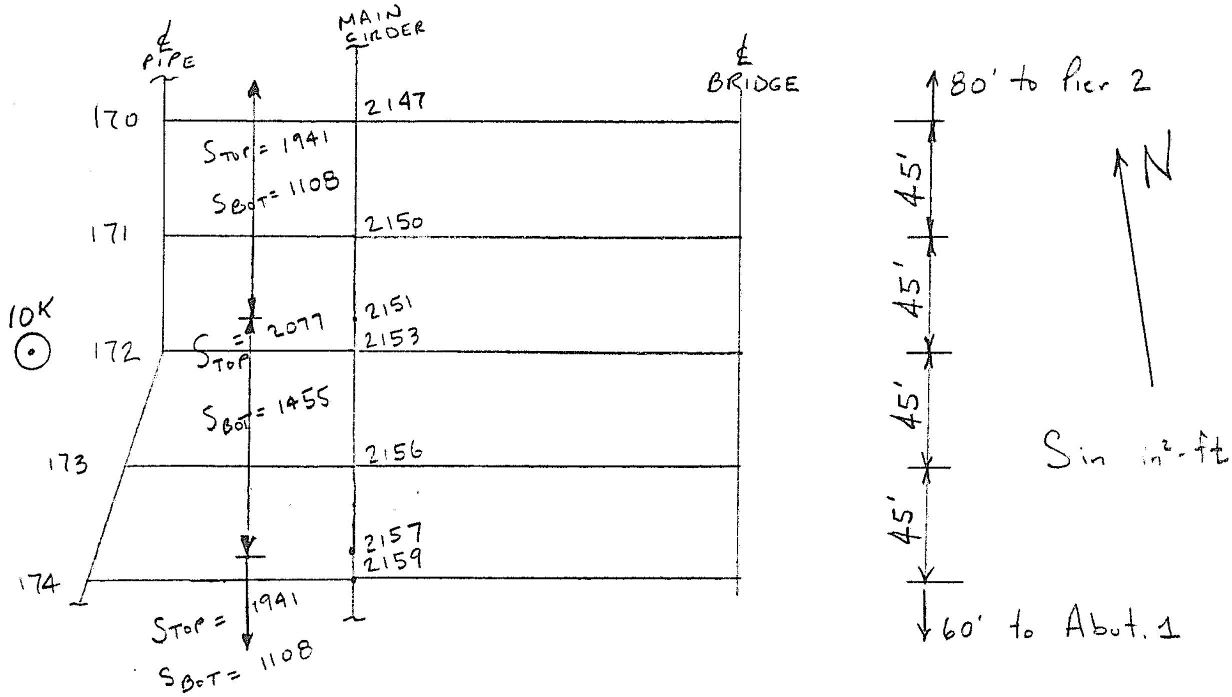
TASK NO. 52 TASK TITLE Special Pipeline Design - Yukon River Bridge

SUBJECT Technical Concerns SHEET NO. C11 of 20

AS 64 MP 361.5 FILE NO. 61.1

REV. NO. 0 BY KJM DATE 9/27/82 CHKD. BY ______ DATE ______



PT	K-" D.L. moment (w/operating gas line)	K-" D.L + 10K vertical	K-" Δ	KSI Δσ BOT
2147	-29568	-29347	221	0.02
2150	146532	148289	1757	0.13
2151	218940	222833	3893	0.29/0.22
2153	245031	249421	4390	0.25
2156	258482	261509	3027	0.17
2157	213439	214920	1481	0.08/0.11
2159	176160	178770	2610	0.20

Form-JVE-2

FM-91-A-002

Assume Truck Loading + Impact

At transition point (node 2151)

Moment truck loading = 5829 K-ft

DL moment (w/o 10^K load) = 218940 K-" = 18245 K-ft

Existing σ = (18245 + 5829) / 1108 = 21.73 Ksi

Remaining to yield = 50 - 21.73 = 28.27 Ksi

Load to yield = $\frac{28.27}{0.29} \times 10$ = 975 Kips

Without ANSYS runs estimate effect on configuration:

Oil lines on both pipeways, gas line under deck.

After strengthening σ = 27 Ksi

Remaining to yield = 50 - 27 = 23 Ksi

Load to yield = $\frac{23}{0.29} \times 10$ = 793 Kips

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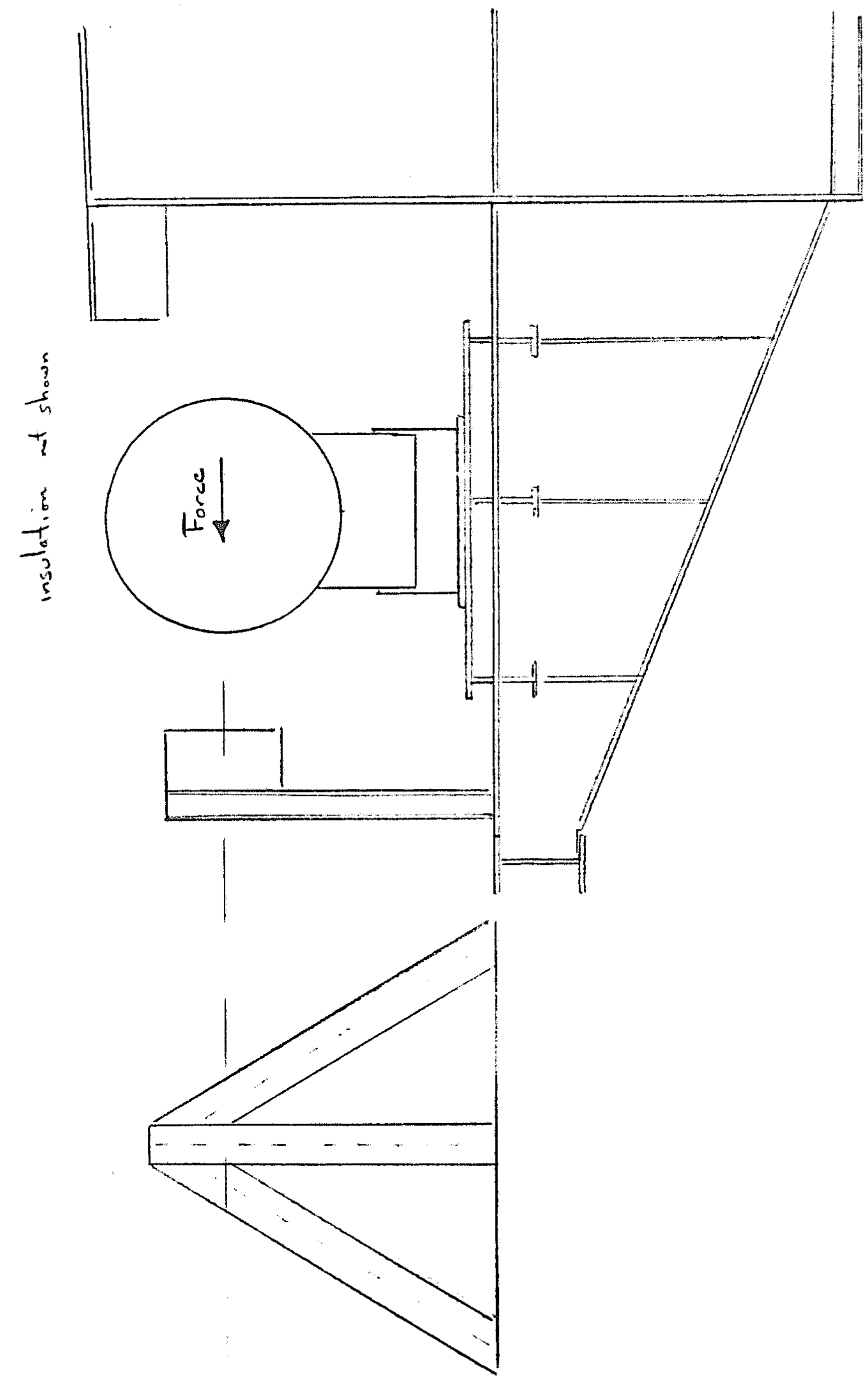
TASK NO. 52 TASK TITLE Special Pipeline Design - Yukon River Bridge

SUBJECT Technical Concerns SHEET NO. C13 of 20

As 64 MP 361.5 FILE NO. 61.1

REV. NO. 0 BY KJM DATE 9.29.82 CHKD. BY ____ DATE ____

Case 3) Horizontal Force - On Bumper



Form-JVE-2

FM-91-A-0C

TASK NO. 52 TASK TITLE Special Pipeline Design - Yukon River Bridge
SUBJECT Technical Concerns SHEET NO. C14 of 20
As 64 MP 361.5 FILE NO. 61.1
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PRELIMINARY SIZING OF BUMPER SYSTEM :

Used W5×19 , $S = 9.94 \text{ in}^3$

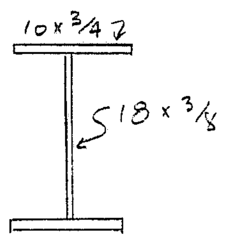
Assume even load distribution since load point at tip is identical. Neglect effect of incline on outside beams

Yield Moment $= 3 \times S \times \sigma_{YLD} = 1491$ K-in

Then Yield load $= \frac{1491 \text{ K-in}}{55 \text{ in}} = 27.1^K$

Check effect on cantilever girder

Conservatively use section properties for 18" depth (same as edge beam depth)



$$I = \frac{18^3 \times 3/8}{12} + 2(10 \times .75)(9.375)^2$$
$$= 182 + 1318 = 1500 \text{ in}^3$$

Yield moment $= 1500 \times \sigma_{YLD} / 9.75 = 7692$ K-in

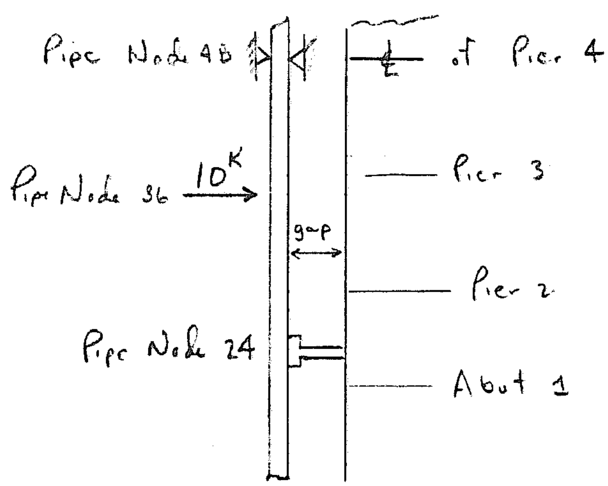
Yield load $= \frac{7692 \text{ K-in}}{(55 \text{ in} + 9 \text{ in})} = 120$ Kips

BUMPER BEAMS ARE CRITICAL USE $\underline{27^K}$

CASE 4) HORIZONTAL FORCE - TOWARD WEB

The critical alternative is Alternative A since Alternative B shows bumper stops next to all piers, and there is a longer distance for pipe to travel to contact web

Thus use Alternative A configuration for critical event:



Initial gap - assume 2'-6" (conservative)

Use coefficient of friction 0.05 to allow most movement

Apply 10^K horizontal load at node 136 (gas node number at bridge node 36)

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TASK NO. 52 TASK TITLE Special Pipeline Design - Yukon River Bridge

SUBJECT Technical Concerns SHEET NO. C16 of 20

As 64 MP 361.5 FILE NO. 61.1

REV. NO. 0 BY KJM DATE 9.30.82 CHKD. BY ____ DATE ____

Results of ANSYS analysis indicate the concentrated 10^K load at node 136 produces a movement of 0.78" at node 136 (maximum).

Therefore, conservatively assume that the force is equal to the maximum frictional resistance:

$$F = 900' \times 0.482\ ^{K}/ft \times 0.05 = 21.7^{K}$$

Form-JVE-2

FM-91-A-002

OBJECTIVE

Determine the maximum thrust exerted on the 48 inch gas line as a result of a Postulated hole during Operations.

DESIGN CONDITIONS

Operating Pressure = 1260 PSIG
Operating Temp. = 0°F Min.

CALCULATIONS

$$\text{Thrust} = \frac{W}{3600\,g} V_s \qquad \text{Eq. 1}$$

where, W = gas discharge (Lbs/hour)
g = Acceleration of Gravity (32.2 ft/sec²)
V_s = Sonic Velocity (ft/sec)

from Reference 1, Page 3.2, Equation 3.1, we may write

$$W = \frac{C K P_1 K_b \sqrt{M} \; (A)}{\sqrt{T} \; \sqrt{Z}} \qquad \text{Eq. 2}$$

where, W = gas discharge (Lbs/hour)
C = Coefficient based on ratio of specific heats, Use Value for Methane from Figure 3-2 of Ref. 1
= 346

K = Coefficient of Discharge.
USE a conservative value of 1.0

P_1 = upstream pressure PSIA (1275)

K_b = Correction factor due to backpressure.
1.0 from Fig. 3-3

M = Molecular Weight of gas

A = Effective discharge Area (sq. in.)

T = Absolute Temp. of gas (460 °R)

Z = Compressibility factor for deviation from a perfect gas

From Ref. 1, Page 16-1

$$\rho_v = \frac{M\,P}{R\,T\,Z}$$ Eq. 3

where,

ρ_v = gas density (Lbs/ft³)

P = pressure (PSIa) = P_1

R = gas constant $\left(10.73 \frac{psia \cdot ft^3}{°R \cdot lb\,mol}\right)$

From Ref. 2, page 10-38

$$c = \sqrt{\frac{\gamma P}{\rho}}$$ Eq. 4

Where,

c = Velocity of sound = V_s

$\gamma = \frac{C_p}{C_v}$ = 1.30 for methane (Ref. 1, Fig. 3-2)

ρ = mass density = $\frac{\rho_v}{g}$

$P = P_1 \left(144 \frac{in^2}{ft^2}\right)$

Combining Eqs. 1, 2, 3 & 4 Above, we may write

$$\text{Thrust} = \frac{C\, P_1 A \sqrt{M}\, \sqrt{\frac{C_p}{C_v}}\, \sqrt{P_1}\, \sqrt{144}\, \sqrt{R}\, \sqrt{T}\, \sqrt{Z}\, \sqrt{g}}{\sqrt{T}\, \sqrt{Z}\, (3600)\, g \sqrt{M}\, \sqrt{P_1}}$$

$$= \frac{346 \sqrt{1.3 \times 10.73 \times 144}}{3600 \sqrt{g}} \; P_1 A$$

or,

$$\text{Thrust} = 0.76\, P_1 A = (0.76)\, 1275\, A$$

$$= \underline{\underline{969\, A^{in^2}}}$$

References

1. Engineering Data Book, Gas Processors Suppliers Association, 5th Rev., 1981, Tulsa, OK.

2. Handbook of Engineering Fundamentals, Edited by O.W. Eshbach, John Wiley & Co., 1963.

GULF INTERSTATE ENGINEERING COMPANY — MICHAEL BAKER, JR., INC.

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TASK NO. 52 TASK TITLE Special Pipeline Design-Yukon River Bridge

SUBJECT Technical Concerns SHEET NO. C20 of 20

AS 64 MP 361.5 FILE NO. 61.1

REV. NO. 0 BY KJM DATE 9.30.82 CHKD. BY ______ DATE ______

Using results of C17-C19;

Pipeline: Critical event is Force up = 18.1^K

$$\text{Area} = \frac{18.1^K}{0.969^K/_{in^2}} = 18.68\,in^2$$

$$\text{Diameter} = 2 \times \left(\frac{18.68}{\pi}\right)^{1/2} = 4.88\,in$$

Bridge: Critical event is Force toward web = 21.7^K

$$\text{Area} = \frac{21.7^K}{0.969^K/_{in^2}} = 22.39\,in^2$$

$$\text{Diameter} = 2 \times \left(\frac{22.39}{\pi}\right)^{1/2} = 5.34\,in$$

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201.18

GOA-82-2177

October 8, 1982

"BUSINESS" Information for Federal Government purposes in accordance with 10 CFR 1504 (F.R. Vol. 46, No. 240, December 15, 1981, pages 61222 thru 61234).

Mr. A. G. Ott
State Pipeline Officer
Department of Natural Resources
1001 Noble Street
Suite 350
Fairbanks, AK 99701

Subject: Gas Pipeline on the Yukon River Bridge, Response to Technical Questions

Dear Mr. Ott:

Pursuant to agreements reached at a meeting held in Seattle on April 1-2, 1982, between representatives of Northwest Alaskan Pipeline Company (NWA), Alyeska Pipeline Service Company (APSC), the Office of the Federal Inspector (OFI), and the Alaska State Pipeline Coordinator's Office (SPCO), NWA has undertaken the preparation of the enclosed supplemental report:

Gas Pipeline on the Yukon River Bridge,
Response to Technical Questions,
Document No. H-17, Rev. 0, 1 October 1982

Submission of this report concludes the structural analysis requested and determined by the State of Alaska to be required in order to make a decision regarding use of the Yukon River Bridge for the Alaska Natural Gas Transportation System (ANGTS).

Further questions, should they arise on this report, or the more fundamental question of ANGTS use of the bridge, should be promptly referred to Mr. R. N. Hauser, 714/975-3050.

The enclosed information is considered confidential/proprietary by Northwest Alaskan Pipeline Company and remains the property of Alaskan Northwest Natural Gas Transportation Company, a partnership. The petition attached to a similar letter requests OFI to consider this material "BUSINESS" information pursuant to 10CFR Part 1504. All rights are reserved to the enclosed work, and unauthorized reproduction is prohibited. This material is

Mr. A. G. Ott
GOA-82-2177
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Very truly yours,

George P. Wuerch
Manager, Regulatory
and Governmental Affairs

GPW/wpc
Enclosures (w/3 copies of enclosure)

cc: W. T. Black, OFI, Irvine (enclosure by separate letter)